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(FINAL REPORT)

JANUARY 1972

VOLUME II

Prepared under Contract EHSD 71-14
for
OFFICE OF AIR PROGRAMS
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An appendix is presented which contains a general discussion of fluoride emission control devices; an inventory of pertinent industrial plants and their location; tabulations of the physicochemical parameters of the evolved fluorides; and a bibliography. This appendix accompanies Volume I of the study which determines the engineering and cost effectiveness of control of soluble fluoride emissions from major industrial sources.

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J.M. Robinson (Program Manager), G.I. Gruber, W.D. Lusk, and M.J. Santy

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7. APPENDIX

7.1 FLUORIDE EMISSION CONTROL EQUIPMENT

Two general types of pollution control equipment are currently employed for control of fluoride emission — wet collection equipment and dry collection equipment.

7.1.1 Wet Collection(4303, 4376, 4379)

Fluoride-containing effluent streams typically contain fluorides either as gaseous species or as combinations of particulate and gaseous species. For this reason, the majority of pollutant capture devices used for fluoride removal are of the wet type. Wet collection systems simultaneously remove both gaseous and particulate pollutants though not to the same level of efficiency.

In the collection of gaseous fluorides, the primary removal mechanism in wet collection is the absorption of the gaseous fluoride into water or other suitable solvents. The basic operation consists of the diffusion of the fluoride gas molecules to the water surface. Concentration differentials near the liquid/gas interface serve as the driving force. Control equipment designed applying this principle is characterized by high interfacial surface areas, turbulence in the gas phase, and high diffusion coefficients. Fortunately, in the area of fluoride emission control, the most common gaseous chemical species to be controlled have high solubility in water.

Particulate collection in liquid scrubbers depends upon a somewhat different set of physical processes. The primary collection mechanism is the impaction of solid particulate material on liquid droplets generated in the scrubber. The function of the liquid scrubber is to generate and place in contact with the exhaust gas stream a sufficient number of liquid droplets in the appropriate droplet size range. Additional physical mechanisms by which particulate dispersoids are collected in wet scrubbers are Brownian diffusion, condensation of liquid on the particulate material, and agglomeration. In each case, the relative effective size of the particulate material is increased in the scrubber, thus facilitating its ultimate collection and disposal.

It should be noted that the mechanisms of gaseous and particulate collection in liquid collectors are somewhat different and that a liquid scrubber designed to maximize gaseous fluoride removal may be significantly less effective in the collection of particulate fluoride-containing material. Application of scrubbers to specific industrial effluent cleaning tasks should be made only on the basis of careful consideration of the relative importance of the gaseous and particulate fluoride emissions and analysis of the particle size distribution in the effluent gas stream to be cleaned.

7.1.1.1 Spray Towers/Chambers

A chamber scrubber consists of a chamber into which water or an aqueous solution is introduced through spray nozzles. The gas stream may make a single direct pass through the chamber, or the path may be controlled by a series of baffles. Several such chambers or scrubbers are often used sequentially to produce the desired degree of pollutant removal. These devices are characterized by a very low pressure drop for the gas phase (0.1 to 0.5 inch of water). Water pressure required for spray operation ranges from 20 to 100 pounds per square inch. Water consumption is usually in the range of 1/2 to 2 gallons per 1000 cubic feet of gas treated.(4303)

Spray chambers are used for the removal of both particulate and gaseous pollutants. The efficiencies of these devices are generally rather low for particulate materials and are suitable only for the removal of particulate materials 10 microns in size or larger. For the collection of smaller particulate material, very high water pressures have been successfully used. Water pressures on the order of 300 to 450 pounds per square inch (psi) produce a fog spray which will achieve collection efficiencies of the order of 90% for particles in the 1 to 2 micron size range. The larger water pressure drops required to achieve high efficiency fog spray result in a proportionally higher pump horsepower and operating cost. Baffled spray chambers require higher gas velocities and result in greater gas pressure drops which, in turn, require for greater fan horsepower to recover the lost pressure head and for more expensive ductwork.

The simple spray chamber is often used effectively for gaseous pollution control, especially when treating some of the relatively more soluble pollutants. Surface contact area, an important consideration in gaseous absorption, is relatively low in spray chambers compared with other types of liquid scrubbers. For this reason, simple spray chambers must be very large to produce efficiencies equivalent to more sophisticated liquid collection systems. Exhaust gases containing hydrogen fluoride and silicon tetrafluoride from the phosphate fertilizer industry may be passed through a series of six or more spray towers prior to release to the atmosphere. The overall efficiencies reported for this type of multiple spray installation are greater than 90%. There are no limitations on gas throughput volume other than those imposed by equipment size limits. However, gas flow rates of approximately 800 lb/hr-ft^2 have been demonstrated as the upper limit, to prevent excessive liquid entrainment.(4376)

Spray chambers or towers, because of their simple design, represent one of the most economical control devices to purchase and install. The operating and maintenance expenses associated with this type of device are also low because of the mechanical simplicity. Primary maintenance problems are caused by the use of small, high-pressure nozzles which may tend to clog under prolonged usage. The low pressure drops (generally less than 1 inch of water) allow the use of inexpensive ductwork and fans to convey the effluent gas stream to the collector.

7.1.1.2 Packed Bed Scrubbers

The packed bed scrubber is similar to the spray chamber described above in that the effluent gas stream to be cleaned is directed through a chamber or tower in which it makes contact with the scrubbing liquid. The high liquid surface area exposed to the gas stream is produced by interaction with the packed bed. The packed bed may be in the form of a fixed packing or loose material which is supported by the action of the gas stream passing through it. This latter type is called a floating bed scrubber. Scrubbing liquid is generally passed through this type of scrubber in a direction crosscurrent or countercurrent to the gas flow.

The fixed packed bed scrubber is not often used strictly for particulate pollutant collection. Operating problems have been encountered when this type of collector is utilized to clean a gas stream containing an excessively high concentration of particulate material. Therefore, in conjunction with this type of equipment, some form of dry collection equipment is used that eliminates much of the particulate load on the wet scrubber and helps prevent clogging.

The floating bed units, in which the packing is supported by the upward motion of the exhaust gas stream, are reported to be more resistant to clogging caused by particulate collection than the fixed packed bed units.(4045, 4304) This reported increased ability to handle particulate contaminant is attributed to the relative motion between the packing materials which produces a self-cleaning action and allows the collected particulate material to be removed by the liquid flow. High particulate removal efficiencies (95 to 98 %) have been reported for the floating bed scrubbing units.

The primary application of the packed bed scrubber has been in the removal of gaseous fluoride pollutants other than SiF_4. Gaseous silicon tetrafluoride, the most common fluoride pollutant, may cause considerable maintenance problems in this type of installation by hydrolyzing to form silica hydrate, a solid which tends to clog the packed bed, thus increasing air flow resistance and eventually making the scrubbing system inoperative.

A condition known as flooding occurs when the upward gas velocity in the packed tower reaches a point at which there is a hold-up of liquid phase on the packing. In this condition, the liquid held in the packing builds up and eventually increases the pressure drop across the packed tower unit to the point where liquid will be entrained and carried out with the exhaust stream. Care must be taken in the design and operation of tower equipment to ensure that this flooding condition is avoided and a reasonable pressure drop is maintained. Properly designed packing materials allow a high liquid surface area to be maintained within the scrubber.

Operation at proper liquid-to-gas flow ratios can achieve high gaseous pollutant removal at relatively low gas flow resistances. Packing materials commonly used are plastic materials of various shapes, including rings, sprial rings, berl saddles, and other shapes which allow a high ratio of surface area to volume.

Utility consumption for the packed bed scrubber depends on the design of the bed, the packing material used and the collection efficiency desired. Typical water consumption for the packed bed scrubber ranges from 5 to 10 gpm per 1000 CFM. Normal packed scrubber design dictates a pressure drop of from 1 to 10 inches of water with a total horsepower requirement of 0.3 to 2.8 for fan and pumping costs. Efficiencies of 95 to 98% have been realized for both particulate and gaseous control, although not necessarily concurrently.

The choice between crossflow and countercurrent scrubber design is dependent on the particular application. However, generally the crossflow scrubber is applied to situations where the bed depth is less than 6 feet and countercurrent design is applied at bed depths of 6 feet or more. These applications are based on the lowest combination of installed capital cost and operating cost.

7.1.1.3 Wet Cyclone Scrubbers

Wet cyclones are characterized by tangential entry of the air stream to be cleaned. The air stream passes through the collector in a spiral path. The liquid stream is directed outward from the center of the circular collection chamber. The cyclonic scrubber thus possesses some of the characteristics of both the simple dry cyclone collector and the spray chamber.

Particulate collection is accomplished by combining centrifugal acceleration of the particles toward the chamber wall with the action of the spray droplets in contacting and removing the particle. Particulate collection efficiences are generally in excess of 90% for particles 5 microns or larger. Gaseous fluoride capture is produced by the intimate turbulent contact between the exhaust gas stream and the water particles generated by spray nozzles and air stream shear forces within the scrubbing unit. Liquid requirements are generally on the order of 2 to 10 gallons of water per 1000 cubic feet of gas treated. Gaseous collection efficiencies range up to 99% with pressure drops of 1 to 8 inches of water. Total fan and pump horsepower vary from 1 to 2 per 1000 CFM. Wet Cyclones have been designed to treat up to 100,000 CFM.

In summary, the wet cyclone has desirable characteristics when the gas stream to be cleaned contains both particulate and gaseous materials. The wet cyclone has an adequate capacity for handling high input dust loadings and produces acceptable collection efficiencies for both medium-sized (>5 microns) particulate and gaseous pollutants. Where extremely high particulate collection efficiencies are required, however, the wet cyclone is used in conjunction with other more efficient collection units. The purchase, installation and operating costs associated with cyclonic scrubbers are comparable with those of packed bed units for situations where the exhaust gas stream to be cleaned represents a high gas flow rate; however, the cyclonic scrubber requires less maintenance.

7.1.1.4 Self-Induced Spray Scrubbers

In this type of scrubber, the gas liquid contact is created as a result of impingement of the carrier gas upon a liquid. The performance characteristics are thus dependent upon the gas flow rate through the collector. The effluent gas stream to be cleaned is impinged upon the surface of the scrubbing liquid; the scrubbing liquid is fragmented and broken into droplet sized particles by the kinetic energy in the gas stream. The liquid droplets formed are entrained, and the effluent gas stream is passed through further sections in which turbulent contact between the liquid and gas phases occur.

Particulate collection efficiency approaches 90% for particles 2 microns and larger. For medium efficiency collection units of this type, pressure drops range between 3 and 6 inches of water. The entrained water droplets and the collected particulate material are removed in the final demisting stage of the induced spray scrubber.(4172) This type of equipment is particularly applicable to gas streams with high dust loadings since continuous removal of sludge can be accomplished with the installation of a screw conveyor. No pumping horsepower is required since the water remains at essentially atmospheric pressure and is atomized by the gas stream.

Another advantage of the induced spray collector lies in the fact that construction does not involve close clearances or small orifices. Clogging, which often represents the bulk of the maintenance problems in wet collectors, would not be expected under normal operating conditions.

Gaseous collection efficiency in the self-induced spray scrubber has been reported to be greater than 99% for hydrogen fluoride and silicon tetrafluoride removal. The control system reported in these observations was a two-stage scrubbing operation with sequential induced spray collectors. Liquid-to-gas requirements are generally lower for this type unit than for most other wet collectors. Liquid requirements range between 1/4 to 3 gallons of liquid per 1000 cubic feet of gas. Fan horsepower for head recovery is from 0.7 to 1.4 per 1000 CFM of treated gas.

7.1.1.5 Orifice Plate Bubblers

The orifice plate bubbler is a class of wet impingement scrubber. The gas stream to be cleaned is passed through a perforated plate and impinged on baffles where the gas jets attain maximum velocity. The impingement baffles are covered by a layer of scrubbing liquid during operation. The gas stream passing through the baffle plate prevents the flow of liquid through the perforated plate. Intimate mixing of the gas streams and the liquid occurs facilitating both gas transfer to the liquid phase and particulate collection by the scrubbing liquid.

Particulate collection efficiencies from 90 to 95% have been reported for 2-micron-diameter dust particles. Several stages of perforated plate and impingement baffle may be assembled into a single collector unit. The particulate removal efficiency is directly related to the number of plates used in the scrubber. As is usual in the design of wet collectors, a mist eliminator is used following the last baffle plate section. Pressure drop through the impingement baffle system has been reported between 1 to 10 inches of water depending upon the size and number of perforations used, and the number of impingement plates in the collector.(4303)

Gaseous fluoride removal efficiencies of between 99 to 99.5% have been reported for the orifice plate type bubblers in application in the aluminum industry.(4605) High collection efficiencies for both particulate and gaseous pollutants make this unit applicable in a wide range of control situations. Water usage runs from 1 to 5 gpm per 1000 CFM and the total (fan and pump) horsepower requirements range from 0.5 to 3 per 1000 CFM.

Clogging has not proved to be a problem in this equipment even though the perforations in the plate are typically only 1/4 inch or less in diameter. Clogging is prevented by high (75 ft/sec or more) gas velocities through these orifices which agitate the liquid on the surface of the plate and keep the dust particles in suspension.

7.1.1.6 Venturi Scrubbers

The basic distinguishing design feature of the venturi scrubber is the passage of the exhaust gas stream through a venturi-type constriction. In this constriction, high linear gas velocities of the order of 12,000 to 42,000 feet per minute are attained. The scrubbing liquid is usually introduced normal to the gas flow at or near the minimum flow area of the venturi. The high gas velocity at this point atomizes the scrubbing liquid into fine droplets that are maintained in turbulent contact with the gas stream.

Particulate collection efficiencies in the venturi scrubber are directly related to the gas phase energy input. Gas pressure drops of 10 to 100 inches of water are common in this type unit with particulate collection efficiency for submicron particles approaching 99% at the higher pressure drops. The freedom from clogging afforded by the relatively simple liquid distribution system of this type unit makes possible the treatment of exhaust streams containing high dust loads. The high particulate removal efficiency further makes the venturi scrubber most applicable when particulate removal is of primary importance.

The intimate gas-liquid contact obtained in this type unit allows the efficient removal of gaseous as well as particulate pollutants. Gaseous fluoride removal efficiencies of from 80 to 99% have been reported in the aluminum industry. The venturi pressure drops associated with these reported efficiencies ranged from 15 to 50 inches of water.(4303, 4305)

Scrubber liquid requirements for this type of control equipment range from 3 to over 8 gallons per 1000 cubic feet of gas.

7.1.1.7 Jet Scrubber

Another type of scrubber operated on the venturi principle is the jet scrubber or ejector venturi design. As in the case of the standard venturi scrubber, the basic operating principle consists of passage of the exhaust gas flow through a restrictive orifice. In the ejector venturi design, the energy impelling the gas stream through the orifice comes from a high pressure liquid spray rather than from the gas phase pressure drop across the collecting unit i.e., water is used to aspirate the dust laden gas through the ejector. The ejector provides the head for the gas, although large induced drafts (above several inches of water) are usually avoided to maintain a high entrainment ratio. The larger the entrainment ratio, the less water is used for a given gas flow rate. Typical water usage ranges from 50 to 100 gpm per 1000 CFM with a pressure drop of 50 to 100 psi for the water across the ejector. This amounts to 1 to 5 pump hp per 1000 CFM. Particulate and gaseous collection efficiencies experienced with the ejector venturi design are comparable with those attained in conventional venturi scrubbing. In both devices, the air stream is brought into intimate and turbulent contact with a fine droplet spray.

The jet scrubber is usually followed by a baffled or settling chamber to capture the water treated particulate matter and water droplets. The main use for this type of equipment is in situations where it is not economical to add a fan to the system.

A wide range of sizes is available in this type of collection unit and multiple banks of ejector venturis have been used to control large process emission sources.

7.1.1.8 Dynamic Wet Scrubbers

In the dynamic wet scrubber, liquid is mechanically sheared into fine droplets and then contacted with the dust laden gas stream. The shearing usually is accomplished by injecting the water into fan blades which simultaneously mix the water and dust streams and recover the lost pressure head of the effluent stream. The wetted impeller and a housing hold the collected dust particles and prevent reentrainment. The dust collection efficiency is approximately 95% for 1 micron particles. No pressure drop incurred by the process stream, however, there is a 3 to 20 hp/1000 CFM requirement for the fan to disperse the water and recover the head. Many of the higher horsepower dynamic units are being displaced with venturi scrubbers. Typical water consumption varies from 3 to 5 gpm per 1000 CFM. Good gaseous collection efficiencies can be expected from the dynamic wet scrubber because of the intimate mixing of the water and the process stream.

7.1.2 Dry Removal Systems(4303, 4376, 4379)

Since the primary fluoride pollutants are gaseous species or combinations of gaseous species and nonsoluble fluoride particulate species, dry collection systems, which have limited ability for removal of gases from effluent streams, are seldom used. Under certain conditions, dry collection systems have been applied to fluoride emissions control either to decrease the particulate load on subsequent control equipment or to collect a solid adsorbant that has been used to reduce the stream's gaseous fluoride content. In either case, the dry collection equipment is usually followed by secondary or even tertiary treatment. Three main classes of dry collection equipment are available : mechanical collection equipment, electrostatic precipitation, and fabric filtration.

7.1.2.1 Mechanical Collectors

Mechanical collectors (inertial separators) have proven to be reliable collectors of dry fluoride particulate material in a number of air pollution control applications. These devices collect particulate material by the use of centrifugal force, gravitational force, or by rapid changes in the direction of the dust laden stream. Mechanical devices are simple to construct, relatively inexpensive, and operate at moderate pressure drops. Generally, the efficiency of the mechanical collector will increase markedly with increased dust loadings , thus, it is often used as a pre-collector preceding more efficient control equipment which is susceptible to overload. Common types of dry mechanical collectors employed in industry include the settling chamber, the louver type collector, the cyclone, the impingement collector, and the dynamic collector.

Settling Chamber.(4379) The settling chamber directs the dust laden gas into an oversized duct where the gas velocity drops to a point where the entrained particles drop out because of the force of gravity. This type of equipment is used in relatively high particulate concentrations (above 5 grains/ft^3) with particles sizes of 50 microns or larger. Dust collection efficiencies range from 50 wt % to 90% depending on dust particle size distribution. The pressure drop through the settling chamber ranges from 0.2 to 0.5 inch water gauge (wg) resulting in a low fan horse power requirement of 0.04 to 0.12 per 1000 CFM of treated gas. Since the efficiency of the settling chamber is relatively low for dispersoid particulates and has no effect on gaseous pollutants, this type of equipment is generally used for pretreatment of a gaseous stream that is to be fed to some more efficient type of collection equipment. The volume of gas that is treated by this type of equipment is limited only by the space available for the unit designed to treat that volume. The typical gas velocity through the chamber ranges from 5 to 10 feet per second.

Baffle Chamber.(4379) In the baffle chamber, settling is aided by using the momentum of the heavy particulate matter to separate it from the carrier gas. The dust laden gas enters the baffle chamber and is directed downward around a baffle and out the top of the chamber. The heavy dust particles tend to continue moving downward and are separated from the gas stream. They drop out a small opening in the bottom of the chamber and are collected. The baffle chamber is used for the same type of conditions as is the settling chamber with the advantage of a smaller space requirement. Gas velocities of 20 to 40 feet per second are typical in the baffle chamber with a pressure drop of 0.1 to 0.5 inch of water. The fan horse power requirement needed to compensate for this pressure drop is 0.02 to 0.12 per 1000 CFM of treated gas. The baffle chamber has a collection efficiency of from 50 to 90% depending on the dust particles to be removed (usually above 50-micron diameter).

Skimming Chamber.(4379) The skimming chamber is similar to the baffle chamber in that it uses the greater momentum of the dust particles to separate them from the gas stream. The dirty gas stream enters an enclosed metal scroll tangentially and the dust is carried to the edge by inertia. A concentrated dust stream is skimmed from the edge of the scroll and sent to a secondary cleaner. Gas velocities of 35 to 70 feet per second are typical for this type of equipment. Efficiencies of 70% are obtainable with particles 20 microns in diameter. Pressure drops of up to 1 inch of water can be expected with a resulting fan horsepower requirement of from 0.02 to 0.24 per 1000 CFM. The limiting size for this type of equipment is 50,000 CFM.

Louver Type Collectors.(4379) This type of equipment also employs the difference in momentum between the dust particles and the carrier gas to separate out the dust. The incoming gas must make a sharp bend in order to escape through the louver (slots) in the wall. The heavier dust particles are carried to the end of the apparatus where they are carried out by a small portion of the original gas stream in a concentrated stream. Efficiency of 80% can be obtained on 20-micron particles at gas velocities of 35 to 70 feet per second. Flow rates are limited to 30,000 CFM for this type of equipment. A pressure drop of 0.5 to 2 inches of water can be expected through this type of equipment requiring from 0.12 to 0.48 fan hp per 1000 CFM to return the gas stream to pretreatment pressure conditions.

Dry Cyclones.(4379) In a cyclone, the dust laden gas enters the top of the apparatus tangentially, forming a vortex that extends downward toward the bottom of the cone-shaped base. At this point the gas then reverses its direction and moves up the center of the outer vortex in a vortex core. The separation of the dust occurs during the downward flow of gas when the inertia of the particles forces them out of the gas stream toward the wall of the cyclone. At the bottom of the cone, the particles continue to move downwards because of their momentum in that direction and are collected through a hole at the base of the cone.

The simple cyclone is typically applied to streams up to 50,000 CFM and can obtain 50% efficiency on 20-micron particles. Pressure drops of 0.5 to 3 inches of water are typical with gas velocities of 35 to 70 feet per second. Fan horsepower requirements are from 0.12 to 0.74 per 1000 CFM to recover the lost pressure head.

There are several modifications of the simple cyclone also employed as dust collection equipment. The high efficiency cyclone employs a relatively smaller diameter and higher gas velocities in order to obtain a greater efficiency. Efficiencies of 80% have been obtained on 10-micron particles. Flow rates in this type of cyclone are limited to 12,000 CFM with an increased pressure drop of 3 to 5 inches of water because of the increased gas velocities. The larger pressure drop dictated by this equipment requires a proportionally larger fan horsepower requirement in order to recover the lost pressure head. Another common variation on the simple cyclone is the multiple cyclone in which many small diameter cyclones are employed to treat the same amount of gas as a conventional cyclone. The effect of this approach is to decrease the effective diameter and increase the efficiency. An efficiency of 90% is nominal for 7.5-micron particles. The pressure drop and fan horsepower for the multiple cyclone is similar to the high efficiency cyclone.

Impingement Collector.(4379) The impingement collector also uses the higher momentum of the dust particles to separate them from the carrier gas. The dirty gas is accelerated by a venturi and the particle momentum carries the dust particles through a slot in a facing metal plate where they impinge on another plate and are collected. The carrier gas tends to diffuse away from the path of the dust particles. It strikes the first metal plate and is carried away rather than going through the slot. This type of equipment can produce a 90% efficiency on 10-micron particles with a pressure drop of from 1 to 2 inches of water. Almost unlimited flow rates are handled by impingement equipment with gas velocities of from 50 to 100 feet per second. Fan horsepower requirements for head recovery are from 0.24 to 0.48 per 1000 CFM.

Dry Dynamic Collector.[4379] The dry dynamic collector is unique in that it uses a specially designed fan to separate the dust particles from the carrier gas and thus has no effective pressure drop. The gas stream is drawn into the collector and accelerated by the impellers of the fan causing the heavy dust particles to be thrown to the outside of the fan chamber. Here they are collected as a concentrated stream and sent to a hopper where they settle out. Since the dynamic collector employs a fan, there is no pressure drop through the equipment and the only utility required for this equipment is the horsepower for the collector itself. The horsepower required for a dynamic collector is slightly greater than for a fan for the same duty, since the mechanical efficiency is somewhat smaller for the collector. Normally the dynamic collector can handle up to 17,000 CFM of dirty gas with efficiencies of 80% on 15-micron particles.

7.1.2.2 Electrostatic Precipitation(4303)

Electrostatic precipitators use an electrical field for charging the particles in the incoming, pollutant-laden gas causing the charged particles to migrate to a collecting electrode because of the electrical field. Particles are collected on the opposite-polarity electrode and transferred to storage for disposal. Control equipment of this type has had extensive application in many fields of pollution control. A primary advantage of electrostatic precipitators is the relatively low operating costs of these units. Power requirements are low with the gas pressure drop rarely exceeding 1/2 to 1 inch of water. Additional power must, of course, be supplied in the form of electric energy required to ionize and collect the particulate material. The total power requirements for electrostatic precipitator units, however, are low compared with power requirements to attain equivalent efficiencies with other collecting mechanisms; they range between 0.1 and 0.6 kw per 1000 CFM. Electrostatic precipitation units are commonly designed to operate at greater than 90% particulate removal on particles of 2 microns or less with gas flow rates from 10,000 to 2,000,000 CFM. The initial cost (purchase and installation) of electrostatic precipitation equipment is high relative to initial costs for mechanical collectors or wet scrubbing systems.

7.1.2.3 Fabric Filtration(4303)

The third class of dry collection equipment which must be considered in a survey of fluoride emissions control equipment is fabric filters. In this type of unit, the exhaust gas stream to be treated is passed through a fabric filter bag which collects the particulate material in the exhaust gases while allowing the gases to pass through to the stack for emission. Very large areas of fabric are used to filter gas streams. The pressure drop or resistance to air flow in fabric filter units increases as the dust loading builds up on the fabric. In general, the range of pressure drops for this type of unit is between 5 and 10 inches of water. Various cleaning mechanisms are used periodically to remove collected particulate material from the fabric filters.

Particulate collection efficiency for this type of unit often exceeds 99.5%. Fabric filter units are relatively unaffected by dust loading or gas throughput up to their design capacity. For this reason they represent one of the most positive and efficient particulate control devices available. When used in conjunction with a solid adsorbent substance, fabric filtration can achieve a high degree of gaseous pollutant removal in fluoride control applications.

Fabric filtration suffers from two major limitations. Humid gas streams cause problems because of caking and binding of the collected particulate material on the fabric surface. This causes greatly increased pressure drop and, in some cases, prevents air flow through the filter installation. The second major limitation is in the cleaning of high temperature exhaust gases. Certain fabric filter materials, such as glass fibers and aromatic polyimide fabrics, have the ability to withstand exhaust gas streams up to 550°F. For gas temperatures above this level, or when it is desirable to use less expensive filtering materials such as nylon, cotton or wool, the gas stream must be cooled prior to entry into the fabric filter unit.

7.2 PLANT LOCATIONS

Inventories of industrial plant locations and capacities were prepared for the industries which are known or potential sources for the emission of significant quantities of soluble fluorides to the atmosphere. The industries covered are: phosphate rock processing; iron and steel production; primary aluminum smelting; coal burning, steam electric power generation; hydrogen fluoride production; clay products; glass products; enamel frits; and non-ferrous metal smelters.

7.2.1 Phosphate Rock Processing

Tables 7-1 through 7-5 list capacities and plant locations for the manufacture of: wet-process phosphoric acid, normal superphosphate, triple superphosphate, ammonium phosphates, and elemental phosphorus.

7.2.2 Iron and Steel Production Plant Locations

There are 51 important locations where iron and steel are produced. The major concentrations of iron and steel mills are in western Pennsylvania, northern Ohio, and around the lower tip of Lake Michigan (Illinois and Indiana). Large iron and steel plants are located in 12 other states as well. These plants are listed in Table 7-6 (compiled from References 4006 and 4275).

Not listed in the table are 112 electric arc furnaces in 39 locations scattered in 17 states. These include a few relatively large arc furnaces listed as making only carbon steel. Most of these 112 furnaces are relatively small, and the average capacity for the entire group is about 40 tons per heat, their omission is consequently deemed of very little comparative significance.

Attention should be directed to 10 blast furnaces in Utah and 4 blast furnaces in California because of the fact that iron ore mined in the western states may have significant amounts of fluoride. Only one fluoride level in western ore has been found in the available publications: the fluoride content of the iron ore was found to average approximately 3000 ppm (Anon., Fluoride Control At Geneva Works, Intermountain Industry and Review, pp. 22-26, December 1957). This is a higher fluoride level than was reported in England for ironstone, 950 to 1200 ppm [Great Britain,

Table 7-1. Wet Process Phosphoric Acid Plant Locations(4274) and Capacities 1969

State and City	Region	Company	Capacity, Thousand Tons P_2O_5 Per Year	
			Ortho	Super
Arkansas				
Helena	--	Arkla Chem. Corp.	60	
California				
Edison	Bakersfield	AFC, Inc.	17	
Hanford	--	Reserve Oil & Gas	30	
Helm	Fresno	Valley Nitrogen Producers, Inc.	50	
Lathrop	Stockton	Occidental Chem. Co.	18	
Nichols	San Francisco-Oakland	Collier Carbon & Chem. Corp.	9	
Trona	San Bernardino-Riverside-Ontario	American Potash and Chem. Corp.	5	
Delaware				
North Claymont	Wilmington	Allied Chem. Corp.	37	
Florida				
Bartow	--	CF Chemicals, Inc.	650	
Bartow	--	Internation Minerals & Chem. Corp.	170	
Bartow	--	USS Agri-Chemicals, Inc.	120	13
Bartow	--	W.R. Grace & Co.	350	
Brewster	--	American Cyanamid Co.	220	3
Fort Meade	--	U.S. Agri-Chemicals, Inc.	230	
Mulberry	--	F.S. Royster Co.	180	
Pierce	--	Continental Oil Co.	275	
Pierce	--	Farmland Industries, Inc.	220	
Piney Point	--	Borden, Inc.	220	
Plant City	Tampa-St. Petersburg	Central Phosphates, Inc.	275	
Tampa	Tampa-St. Petersburg	Tennessee Corp.	650	
White Springs	--	Occidental Chem. Co.	275	50
Idaho				
Kellogg	--	North Idaho Phosphate Co.	30	15
Pocatello	--	J.R. Simplot Co.	265	17
Illinois				
Depue	--	New Jersey Zinc Co.	160	
East St. Louis	St. Louis	Allied Chemical Corp.	37	33
Streator	--	Borden, Inc.	24	
Tuscola	--	National Distillers & Chem. Corp.	40	
Iowa				
Fort Madison	--	Sinclair Oil Corp.	225	
Louisiana				
Convent	--	Freeport Sulphur Co.	700	
Geismar	--	Allied Chem. Corp.	200	110

Table 7-1. Wet Process Phosphoric Acid Plant Locations(4274) and Capacities 1969 (continued)

State and City	Region	Company	Capacity, Thousand Tons P_2O_5 Per Year	
			Ortho	Super
Mississippi				
Pascagoula	--	Coastal Chem. Corp.	150	
Missouri				
Joplin	--	Farmers Chem. Co.	55	
Joplin	--	W.R. Grace & Co.	35	
North Carolina				
Aurora	--	Texas Gulf Sulphur Co.	500	100
Texas				
Pasadena	Houston	Olin Mathieson Chem. Corp.	225	
Pasadena	Houston	Phosphate Chemicals, Inc.	60	25
Texas City	Galveston-Texas City	Borden, Inc.	60	
Utah				
Salt Lake City	Salt Lake City	Stauffer Chem. Co.	70	51

[*] Total plant capacity is listed under "ortho." Super acids may then be made by evaporating water from ortho acids. The super acid capacities shown here are for those companies with this type of concentrating equipment.

Table 7-2. Normal Superphosphate Plant Locations and Capacities (1969)

State and City	Region	Company	Capacity, Thousand Tons P_2O_5 Per Year	
			Ortho	Super
Alabama				
Bessemer	Birmingham	F.S. Royster Co.	50	
Birmingham	Birmingham	Mobile Chem. Co.	--	
Decatur	--	Alabama Farmers Coop., Inc.	50	
Demopolis	--	Central Farmers Coop., Inc.	50	
Dothan	--	Home Guano Co.	40	
Dothan	--	Mobile Chem. Co.	--	
Montgomery	Montgomery	Continental Oil Co.	--	
Montgomery	Montgomery	Mobile Chem. Co.	--	
Montgomery	Montgomery	Tennessee Corp.	--	
Selma	Montgomery	Centrala Farmers Coop., Inc.	20	
California				
Edison	Bakersfield	AFC, Inc.	100	
Lathrop	Stockton	Occidental Petroleum Corp.	--	
Richmond	San Francisco-Oakland	Stauffer Chem. Co.	50	
Florida				
Cottondale		Wilson & Toomer Fertilizer	50	
Jacksonville	Jacksonville	Wilson & Toomer Fertilizer	125	
Nichols	--	Mobile Chem. Co.	--	
Pensacola	Pensacola	Continental Oil Co.	--	
Pierce	--	Continental Oil Co.	--	
Tampa	Tampa-St. Petersburg	Tennessee Corp.	--	
Georgia				
Albany	Albany	Swift & Co.	--	
Albany	Albany	U.S. Agri-Chemicals, Inc.	--	
Athens	--	F.S. Royster Co.	75	
Atlanta	Atlanta	Swift & Co.	--	
Columbus	Columbus	U.S. Agri-Chemicals, Inc.	--	
Cordele	--	Cotton Producers Assn.	70	
Douglas	--	Columbia Nitrogen Corp.	20	
East Point	Atlanta	Tennessee Corp.	75	
Macon	Macon	Cotton States Fertilizer Co.	40	
Macon	Macon	F.S. Royster Co.	50	
Moultrie	--	Columbia Nitrogen Corp.	100	
Pelham	--	Pelham Phosphate Co.	60	
Savannah	Savannah	Continental Oil Co.	--	
Savannah	Savannah	Kaiser Aluminum & Chem. Corp.	150	
Savannah	Savannah	Mobile Chem. Co.	--	
Savannah	Savannah	Mutual Fertilizer Co.	50	
Savannah	Savannah	Southern States Phosphate & Fertilizer Co.	150	
Valdosta	--	Georgia Fertilizer Co.	75	

Table 7-2. Normal Superphosphate Plant Locations and Capacities (1969) (continued)

State and City	Region	Company	Capacity, Thousand Tons P_2O_5 Per Year	
			Ortho	Super
Illinois				
Ashkum	--	Occidental Petroleum Corp.	25	
Calumet City	Chicago	Swift & Co.	--	
Chicago Heights	Chicago	U.S. Agri-Chemical, Inc.	--	
Danville	--	Continental Oil Co.	--	
Danville	--	National Distillers & Chem. Corp.	--	
East St. Louis	St. Louis	F.S. Services, Inc.	60	
East St. Louis	St. Louis	Mobil Chem. Corp.	--	
Fulton	--	Continental Oil Co.	--	
Morris	--	Gilerist Plant Food Co.	--	
National Stock Yards	St. Louis	Swift & Co.	--	
National Stock Yards	St. Louis	Continental Oil Co.	--	
Streator	--	Borden, Inc.	--	
Indiana				
Fort Wayne	Fort Wayne	Mobil Chem. M Co.	--	
Indianapolis	Indianapolis	Borden, Inc.	--	
Indianapolis	Indianapolis	Indiana Farm Bureau Coop. Assn, Inc.	90	
Indianapolis	Indianapolis	International Minerals & Chem. Corp.	--	
Indianapolis	Indianapolis	F.S. Royster Co.	90	
Jeffersonville	Louisville	Indiana Farm Bureau Coop. Assn, Inc.	40	
Iowa				
Dubuque	Dubuque	Mobil Chem. Co.	--	
Humboldt	--	Continental Oil Co.	--	
Mason City	--	International Minerals & Chem. Corp.	--	
Perry	--	W.R. Grace & Co.	--	
Kansas				
Kansas City	Kansas City	Gulf Oil Corp.	40	
Kentucky				
London	--	Continental Oil Co.	--	
Russellville	--	Borden, Inc.	25	
Winchester	Louisville	Southern States Coop, Inc.	20	
Louisiana				
Baton Rouge	Baton Rouge	Louisiana Agricultural Supply Co., Inc.	25	
Harvey	New Orleans	Swift & Co.	--	
Lake Charles	Lake Charles	Kelly, Weber & Co., Inc.	30	
New Orleans	New Orleans	U.S. Agri-Chemicals, Inc.	--	
Shreveport	Shreveport	Mobil Chem. Co.	--	

Table 7-2. Normal Superphosphate Plant Locations and Capacities (1969) (continued)

State and City	Region	Company	Capacity, Thousand Tons P_2O_5 Per Year	
			Ortho	Super
Maine				
Searsport	--	W. R. Grace & Co.	--	
Searsport	--	Northern Chem. Industries, Inc.	--	
Maryland				
Baltimore	Baltimore	Continental Oil. Co.	--	
Baltimore	Baltimore	W.R. Grace & Co.	--	
Baltimore	Baltimore	Kerr-McGee Chem. Corp.	--	
Baltimore	Baltimore	Olin Mathieson Chem. Corp.	--	
Baltimore	Baltimore	F.S. Royster Co.	100	
Massachusetts				
North Billerica	Lowell	Lowell Rendering Co.	30	
North Weymouth	Boston	Continental Oil Co.	--	
Michigan				
Lansing	Lansing	W.R. Grace & Co.	--	
Saginaw	Saginaw	Borden, Inc.	--	
Saginaw	Saginaw	Continental Oil Co.	--	
Saginaw	Saginaw	Farm Bureau Services, Inc.	50	
Minnesota				
Winona	--	Cenex, Inc.	50	
Mississippi				
Jackson	Jackson	Mobil Chem. Co.	--	
Jackson	Jackson	F.S. Royster Co.	50	
Magee	--	Magee Coop.	30	
Marks	--	Riverside Fertilizer Factory	--	
Meridian	--	Atlas Fertilizer & Chem. Co.	--	
Pascagoula	--	Coastal Chem. Corp.	--	
Tupelo	--	International Minerals & Chem. Corp.	--	
Missouri				
Joplin	--	W.R. Grace & Co.	--	
New Jersey				
Carteret	--	Continental Oil Co.	--	
New York				
Buffalo	Buffalo	Continental Oil Co.	--	

Table 7-2. Normal Superphosphate Plant Locations and Capacities (1969) (continued)

State and City	Region	Company	Capacity, Thousand Tons P_2O_5 Per Year	
			Ortho	Super
North Carolina				
Charlotte	Charlotte	F.S. Royster Co.	50	
Greensboro	Greensboro-Winston-Salem-High Point	Continental Oil Co.	--	
Greensboro	Greensboro-Winston-Salem-High Point	Swift & Co.	--	
Greensboro	Greensboro-Winston-Salem-High Point	U.S. Agri-Chemicals, Inc.	--	
Riegelwood	--	Kaiser Aluminum & Chem. Corp.	50	
Selma	--	Mobil Chem. Co.	--	
Wilmington	Wilmington	Mobil Chem. Co.	--	
Wilmington	Wilmington	Swift & Co.	--	
Wilmington	Wilmington	U.S. Agri-Chemicals, Inc.	--	
Ohio				
Cairo	--	Continental Oil Co.	--	
Cincinnati	Cincinnati	International Minerals & Chem. Corp.	--	
Cincinnati	Cincinnati	Mobil Chem. Co.	--	
Cleveland	Cleveland	Continental Oil Co.	--	
Cleveland	Cleveland	Swift & Co.	--	
Columbus	Columbus	Borden, Inc.	--	
Columbus	Columbus	Federal Chem. Co.	--	
Columbus	Columbus	W.R. Grace & Co.	--	
Lockland	Cincinnati	Tennessee Corp.	100	
Toledo	Toledo	F.S. Royster Co.	100	
Washington, Court House	--	Continental Oil Co.	--	
Oklahoma				
Oklahoma City	Oklahoma City	American Cyanamid Co.	50	
Pennsylvania				
Philadelphia	Philadelphia	Kerr-McGee Chem. Corp.	--	
South Carolina				
Charleston	Charleston	Continental Oil Co.	--	
Charleston	Charleston	W.R. Grace & Co.	--	
Charleston	Charleston	Mobil Chem. Co.	--	
Charleston	Charleston	Planters Fertilizer Co.	--	
Charleston	Charleston	F.S. Royster Co.	40	
Spartanburg	--	International Minerals & Chem. Corp.	--	

Table 7-2. Normal Superphosphate Plant Locations and Capacities (1969) (continued)

State and City	Region	Company	Capacity, Thousand Tons P_2O_5 Per Year	
			Ortho	Super
Tennessee				
Chattanooga	--	A.D. Adair & McCarty Bro., Inc.	25	
Knoxville	Knoxville	Continental Oil Co.	--	
LaVergne	--	Tennessee Farmers Coop.	30	
Memphis	Memphis	Mobil Chem. Co.	--	
Mt. Pleasant	--	Mobile Chem. Co.	--	
Nashville	Nashville	Continental Oil Co.	--	
Nashville	Nashville	Federal Chem. Co.	--	
Nashville	Nashville	W.R. Grace & Co.	--	
Nashville	Nashville	U.S. Agri-Chemicals Inc.	--	
Tenco	Knoxville	Tennessee Farmers Coop.	30	
Wales	--	International Minerals & Chem. Corp.	--	
Texas				
Comanche	--	Central Texas Fertilizer Co., Inc.	15	
Galena Park	Houston	American Plant Food Corp.	--	
Houston	Houston	Occidental Petroleum Corp.	--	
Littlefield	--	Caprock Fertilizer Co.	30	
Plainview	--	Occidental Petroleum Co.	--	
Sulphur Springs	--	Farmland Industries, Inc.	50	
Utah				
North Salt Lake	Salt Lake City	Mineral Fertilizer Co.	25	
Virginia				
Chesapeake	Norfolk-Portsmouth	F.S. Royster Co.	100	
Norfolk	Norfolk-Portsmouth	Borden, Inc.	60	
Norfolk	Norfolk-Portsmouth	Farmers Guano Co.	50	
Norfolk	Norfolk-Portsmouth	W.R. Grace & Co.	--	
Norfolk	Norfolk-Portsmouth	Swift & Co.	--	
Norfolk	Norfolk-Portsmouth	Weaver Fertilizer Co., Inc.	60	
Richmond	Richmond	Mobil Chemical Co.	--	
Richmond	Richmond	Richmond Guana Co.	60	
Washington				
Tacoma	Tacoma	Stauffer Chem. Co.	--	
Wisconsin				
Madison	Madison	F.S. Royster Co.	80	
Prairie DuChien	--	F.S. Services, Inc.	120	

Table 7-3. Triple Superphosphate Plant Locations[(4274)] and Capacities (1969)

State and City	Region	Company	Capacity, Thousand Tons P_2O_5 Per Year	
			Ortho	Super
Alabama				
Wilson Dam	--	Tennessee Valley Authority	30	
Florida				
Agricola	--	Swift & Co.	175	
Bartow	--	W.R. Grace & Co.	565	
Bartow	--	International Minerals & Chem. Corp.	450	
Brewster	--	American Cyanamid Co.	400	
Ft. Meade	--	U.S. Agri-Chemicals, Inc.	245	
Green Bay	--	Farmland Industries, Inc.	100	
Mulberry	--	F.S. Royster Co.	510	
Nichols	--	Mobil Chem. Co.	400	
Pierce	--	Continental Oil Co.	400	
Plant City	Tampa-St.Petersburg	Central Phosphate, Inc.	255	
Port Manatee	--	Borden, Inc.	70	
Tampa	Tampa-St. Petersburg	Tennessee Corp.	850	
White Springs	--	Occidental Petroleum Corp.	150	
Idaho				
Conda	--	El Paso Products Co.	128	
Pocatello	--	J.R. Simplot, Co.	130	
Missouri				
Joplin	--	W.R. Grace & Co.	32	
North Carolina				
Aurora	--	Texas Gulf Sulphur Co.	355	
Utah				
Salt Lake City	Salt Lake City	Stauffer Chem. Co.	100	
Washington				
Tacoma	Tacoma	Stauffer Chem. Co.	--	

Table 7-4. Ammonium Phosphate Plant Locations(4274) and Capacities (1969) (continued)

State and City	Region	Company	Capacity, Thousand Tons P_2O_5 Per Year	Product*
Alabama				
Cherokee	--	U.S. Agri-Chemical, Inc.	180	D
Muscle Shoals	--	Tennessee Valley Authority	157	D,L,N
Arizona				
Chandler	Phoenix	Arizona Agrochemical Corp.	35	D,S,
Arkansas				
Helena	--	Arkla Chem. Corp.	100	D
California				
Brea	Anaheim-Santa Ana-Garden Grove	Collier Carbon & Chem. Corp.	50	L
Edison	Bakersfield	AFC, Inc.	88	D,S,
Fontana	San Bernardino-Riverside-Ontario	Kaiser Steel Corp.	24	D
Hanford	--	Reserve Oil & Gas	--	D,S
Helm	Fresno	Valley Nitrogen Producers, Inc.	170	D,M,S
Lathrop	Stockton	Occidental Petroleum Corp.	40	M,L
Nichols	San Francisco-Oakland	Collier Carbon & Chem. Corp.	60	D,M,S
Pittsburg	San Francisco-Oakland	Shell Chem. Co.	12	D
Richmond	San Francisco-Oakland	Chevron Chem. Co.	--	N
Florida				
Bartow	--	W.R. Grace & Co.	200	D
Bartow	--	International Minerals & Chem. Corp.	650	D
Brewster	--	American Cyanamid Co.	200	D
Mulberry	--	F.S. Royster Co.	100	D
Pierce	--	Continental Oil Co.	400	D
Pierce	--	Farmland Industries, Inc.	200	D
Piney Point	--	Borden, Inc.	128	D
Plant City	Tampa-St. Petersburg	Central Phosphates, Inc.	200	D
Tampa	Tampa-St. Petersburg	Tennessee Corp.	390	D,M
White Springs	--	Occidental Petroleum Corp.	309	D,L

*See footnote at end of table.

Table 7-4. Ammonium Phosphate Plant Locations[4274] and Capacities (1969) (continued)

State and City	Region	Company	Capacity, Thousand Tons P_2O_5 Per Year	Product*
Idaho				
Kellogg	--	North Idaho Phosphate Co.	50	D,N,L
Pocatello	--	J.R. Simplot Co.	286	D,L
Illinois				
Chicago Heights	Chicago	Stauffer Chem. Co.	25	D,M
Depue	--	New Jersey Zinc Co.	270	D
Henry	--	W.R. Grace & Co.	100	D,M
Morris	--	Stauffer Chem. Co.	26	L
Streator	--	Bordon, Inc.	37	D,M
Iowa				
Fort Madison	--	Chevron Chem. Co.	--	N
Fort Madison	--	Sinclair Oil Corp.	420	D,L
Kansas				
Lawrence	--	FMC Corp.	--	L
Louisiana				
Donaldsonville	--	Gulf Oil Corp.	300	D,L
Geismar	--	Allied Chem. Corp.	420	D,L
Luling	--	Monsanto Co.	300	D,N
Michigan				
Dearborn	Detroit	Ford Motor Co.	18	D
Mississippi				
Pascagoula	--	Coastal Chem. Corp.	420	D,M,N
Missouri				
Joplin	--	Farmers Chem. Co.	200	D,M
Joplin	--	W.F. Grace & Co.	--	D
North Carolina				
Aurora	--	Texas Gulf Sulphur Co.	220	D

*See footnote at end of table.

Table 7-4. Ammonium Phosphate Plant Locations and(4274) Capacities (1969) (continued)

State and City	Region	Company	Capacity, Thousand Tons P_2O_5 Per Year	Product*
Texas				
Brownfield	--	Goodpasture Grain & Milling Co.	100	L
Dimmitt	--	Elcor Chem. Corp.	25	L
Galena Park	--	American Plant Food Corp.	175	S
Houston	Houston	Occidental Petroleum Corp.	--	D,S
Kerens	--	Nipak	100	D
Pasadena	Houston	Olin Mathieson Chem. Corp.	700	D,M,S
Pasadena	Houston	Phosphate Chemicals, Inc.	50	D
Plainview	--	Occidental Petroleum Corp.	20	D,S
Utah				
Salt Lake City	Salt Lake City	Stauffer Chem. Co.	175	D,M,S,L
Washington				
Kennewick	--	Chevron Chem. Co.	--	N

*

D = Di Ammonium Phosphates

L = Liquid (Ammonium Polyphosphates) Solutions

M = Monoammonium Phosphates

N = Ammonium Phosphates - Nitrates

S = Ammonium Phosphates - Sulfates

Table 7-5. Elemental Phosphorus Plant Locations and Capabilities (April 1969)

State and City	Region	Company	Capacity, Thousand Tons P_4 Per Year	
			Ortho	Super
Alabama				
Muscle Shoals	--	Tennessee Valley Authority	40	
Florida				
Nichols	--	Mobil Chem. Co.	6	
Pierce	--	Continental Oil Co.	30	
Tarpon Springs	Tampa-St.Petersburg	Stauffer Chem. Co.	23	
Idaho				
Pocatello	--	FMC Corp	145	
Soda Springs	--	Monsanto Co.	100	
Montana				
Silver Bow	--	Stauffer Chem. Co.	42	
South Carolina				
Charleston	Charleston	Mobil Chem. Co.	10	
Tennessee				
Columbia	--	Hooker Chem. Corp.	70	
Columbia	Mo	Monsanto Co.	140	
Mt. Pleasant	--	Mobil Chem. Co.	20	
Mt. Pleasant	--	Stauffer Chem. Co.	63	

Table 7-6. Location of Iron and Steel Works (1970)(4006,4275)

State and City	Integrated Iron and Steel Works, Number of Blast Furnaces(a)	Ironworks, Number of Blast Furnaces(a)	Steel Works, Number of Open Hearth Furnaces(b) (Tons/Heat)	Steel Works, Number of Electric Arc Furnaces(c) (Tons/Heat)	Steel Works, Number of Basic Oxygen Furnaces(d) (Tons/Heat)
Alabama					
Birmingham		5			
Gadsden	2			2(370)	2(300)
Jefferson City	8		21(4100)		
Woodward		4			
California					
Alameda			4(600)		
Fontana	4		8(1800)		3(300)
Los Angeles				6(305)	
Torrance			4(280)		
Colorado					
Pueblo	4				2(236)
Delaware					
New Castle				2(300)	
Illinois					
Chicago	1				
East Chicago	8				
Granite City	2				2(440)
Peoria			5(875)		
Riverdale	1				
South Chicago	15		4(1000)	4(600)	2(240)
Indiana					
East Chicago	3		39(7520)	2(240)	4(1040)
Gary	12		36(5400)		
Porter City					2(600)
Kentucky					
Ashland	3				2(360)
Covington			7(630)	3(225)	
Maryland					
Baltimore			18(6000)	6(87)	2(400)
Sparrows Pt	10				

(a) Average blast furnace capacity = 1000 tons/day

(b) Average open hearth furnaces = 2 heats/day

(c) Listed electric arc furnaces = 3.5 heats/day

(d) Average basic oxygen furnaces = 12 heats/day

Table 7-6. Location of Iron and Steel Works[4006,4275] (1970) (continued)

State and City	Integrated Iron and Steel Works, Number of Blast Furnaces[a]	Ironworks, Number of Blast Furnaces[a]	Steel Works, Number of Open Hearth Furnaces (Tons/Heat)[b]	Steel Works, Number of Electric Arc Furnaces (Tons/Heat)[c]	Steel Works, Number of Basic Oxygen Furnace (Tons/Heat)[d]
Michigan					
Dearborn	3				
Detroit				4(700)	11(2030)
Ecorse	4				
Trenton	2				
Minnesota					
Duluth	2		9(1350)		
New York					
Albany				5(80)	
Buffalo	2	4			
Erie City					2(200)
Lackawana	7		14(3100)		3(870)
No. Tonawanda		1			
Syracuse				5(95)	
Troy		1			
Ohio					
Campbell	4				
Canton	2			17(1880)	
Cleveland	8	2	16(3880)		4(900)
Hamilton	1				
Jackson		1			
Lorain	5				
Mahoning Cty			12(2520)		
Mansfield			6(1020)	2(200)	
Middletown	2		6(1860)		2(400)
Portsmouth	2		5(1600)		
Steubenville	5		11(2360)		2(550)
Toledo		2			2(150)
Warren	1			2(370)	2(300)
Youngstown	10				

[a] Average blast furnace capacity = 1000 tons/day

[b] Average open hearth furnaces = 2 heats/day

[c] Listed electric arc furnaces = 3.5 heats/day

[d] Average basic oxygen furnaces = 12 heats/day

Table 7-6. Location of Iron and Steel Works[4006,4275] (1970) (Continued)

State and City	Integrated Iron and Steel Works, Number of Blast Furnaces(a)	Ironworks, Number of Blast Furnaces(a)	Steel Works, Number of Open Hearth Furnaces(b) (Tons/Heat)	Steel Works, Number of Electric Arc Furnaces(c) (Tons/Heat)	Steel Works, Number of Basic Oxygen Furnaces(d) (Tons/Heat)
Pennsylvania					
Aliquippa	5				
Allegheny Cty			59(13,630)	16(800)	4(540)
Beaver City				9(600)	7(985)
Bethlehem	5			6(235)	4(500)
Braddock	6				
Bucks County			9(3550)	4(500)	
Chester			5(750)		
Coatesville			6(870)	3(345)	
Dauphin			4(775)	3(450)	
Duquesne	5				
Erie		1			
Fairless Hills	3				
Farrell	2				
Ivy Rock	2				
Johnstown	5			2(130)	
McKeesport	4				
Mercer City			11(1650)	3(220)	2(300)
Midland	3				
Mifflin Cty				2(58)	
Monessen	3		8(1760)		2(400)
Montgomery Cty					2(280)
Neville Isl.		2			
Philadelphia				2(180)	
Pittsburgh	5				
Rankin	5				
Sharpsville		2			
Sheridan		1			
Tennessee					
Rockwood		2			
Texas					
Dallas			5(1250)		
Houston		1			
Lone Star		1			
Utah					
Provo	3		10(3400)		
Virginia					
Lynchburg		2			

(a) Average blast furnace capacity = 1000 tons/day

(b) Average open hearth furnaces - 2 heats/day

(c) Listed electric arc furnaces = 3.5 heats/day

(d) Average basic oxygen furnaces - 12 heats/day

Table 7-6. Location of Iron and Steel Works(4006,4275) (1970) (continued)

State and City	Integrated Iron and Steel Works, Number of Blast Furnaces[a]	Ironworks, Number of Blast Furnaces[a]	Steel Works, Number of Open Hearth Furnaces (Tons/Heat)[b]	Steel Works, Number of Electric Arc Furnaces (Tons/Heat)[c]	Steel Works, Number of Basic Oxygen Furnaces (Tons/Heat)[d]
Washington					
Seattle				4(280)	
West Virginia					
Weirton	4				2(670)

[a] Average blast furnace capacity = 1000 tons/day
[b] Average open hearth furnaces = 2 heats/day
[c] Listed electric arc furnaces = 3.5 heats/day
[d] Average basic oxygen furnaces = 12 heats/day

84th Annual Report on Alkali, Etc., Works by the Chief Inspectors, 1947, London, H.M. Stationery Office (1948) and 85th Annual Report (1949)].

In general, sintering plants are located at integrated iron and steel works. No separate listing is available.

7.2.3 Primary Aluminum Smelting Plant Locations

There are 29 separate locations in the U.S. where aluminum reduction plants are operated or under construction.

The locations of these reduction plants and their production capacities are listed in Table 7-7.

7.2.4 Coal Burning Steam-Electric Power Plant Locations

Most of the coal consumed in the United States is burned for generation of power by steam-electric power plants. The electric power utility industry used 312,000,000 tons of coal in 1969. The locations of coal burning electric utility plants are given in Table 7-8, along with the coal consumption reported for 1969.

Since total anthracite coal production is only 5,000,000 tons (1968) and is decreasing, the fluoride emissions from combustion of anthracite coal are not considered as significant.

Table 7-7. Plant Capacity for Manufacturing(4273) Primary Aluminum

State and City	Annual Capacity, Tons	Reduction Cell Types*
Alabama		
Sheffield	221,000	HS
Scottsboro	210,000 (planned)	PB
Arkansas		
Arkadelphia	63,000	HS
Jones Mills	122,000	PB
Indiana		
Evansville	175,000	PB
Kentucky		
Hawsville	45,000	PB
Louisiana		
Chalmette	260,000	HS
Lake Charles	35,000	PB
Maryland		
Frederick	90,000	PB
Missouri		
New Madrid	110,000 (planned)	PB
Montana		
Columbia Falls	175,000	VS
New York		
Massena	125,000	PB
North Carolina	128,000	HS
Badin	100,000	PB
Ohio		
Hannibal	240,000	PB
Oregon		
The Dalles	87,000	VS
Trontdale	100,000	PB
Tennessee		
Alcoa	200,000	all
New Johnsonville	140,000	PB
Texas		
Corpus Christi	110,000	HS
Point Comfort	175,000	VS
Rockdale	275,000	PB
Washington		
Bellingham	265,000	PB
Longview	190,000	HS
Tacoma	81,000	HS
Spokane	206,000	PB
Vancouver	100,000	PB
Wenatchee	175,000	PB
West Virginia		
Ravenswood	163,000	PB

*PB = Prebaked Anode
HS = Horizontal Stud Soderberg
VS = Vertical Stud Soderberg

Table 7-8. Location of Coal Burning Steam-Electric Utility Plants (1969)(4382)

State and City	Coal Burned in 1969, 1000 Tons	
ALABAMA		
Bucks	1,274	
Chickasaw	50	
Gadsden	224	
Gorgas	1,865	
Demopolis	1,380	
Wilsonville	3,273	
Pride	2,106	
Pride	1,335	
Stevenson	4,042	
Gantt	23	
Andalusia	96	
TOTAL ALABAMA		15,668
ARIZONA		
Joseph City	397	
TOTAL ARIZONA		397
ARKANSAS		
TOTAL ARKANSAS		0
COLORADO		
Alamosa	3	
Denver	1,514	
Cameo	85	
Boulder	430	
Montrose	55	
Durango	9	
Canon City	126	
Pueblo	1	
Colorado Springs	39	
Fort Collins	2	
Walsenburg	12	
Hayden	541	
Nucla	65	
TOTAL COLORADO		2,882
CONNECTICUT		
Milford	728	
Montville	467	
Norwalk	843	
Stamford	57	
Wallingford	18	
TOTAL CONNECTICUT		2,113
DELAWARE		
Wilmington	817	
Millsboro	467	
Dover	57	
TOTAL DELAWARE		1,341
DISTRICT OF COLUMBIA		
Washington, D.C.	777	
TOTAL DISTRICT OF COLUMBIA		777
FLORIDA		
Red Level	940	
Pensacola	184	
Chattahoochee	192	
Panama City	930	
Tampa	2,286	
TOTAL FLORIDA		4,532
GEORGIA		
Bidd County	155	
Cobb County	209	
Floyd County	740	
Milledgeville	2,963	
Cobb County	1,326	
Brunswick	303	
Daugherty City	404	
Coweta City	1,389	
Cordele	17	
TOTAL GEORGIA		7,506
ILLINOIS		
Bartonville	983	
Peoria	8	
E. Peoria	520	
Bartonville	100	
Montgomery Co.	1,057	
Grand Tower	417	
Hutsonville	481	
Meredosia	805	
Dixon	270	
Chicago	2,608	
Rockford	98	
Joliet	3,995	
Kincaid	2,401	
Pekin	793	
Stickney	1,257	
Rockford	187	
Waukegan	2,021	
Lockport Twp.	3,048	
Joppa	3,511	
Havana	369	
Hennepin	377	
Oakwood	517	
Wood River	1,639	
Moline	18	
Monsanto	267	
Venice	1,022	
Fairfield	36	
Highland	28	
Mount Carmel	60	
Peru	32	
Rochelle	30	
Springfield	512	
Winnetka	22	
Marion	207	
TOTAL ILLINOIS		29,706
INDIANA		
Ind.-Ill.-Line	2,227	
Madison	4,280	
Sullivan	1,125	
Lawrenceburg	2,829	
Mishawaka	763	
Indianapolis	851	
Petersburg	851	
Centerton	769	
Dune Acres	1,298	
Michigan City	342	
Gary	813	
Terre Haute	388	
Edwardsport	447	
New Albany	1,763	
Noblesville	110	
Terre Haute	2. 95	
Rushville	5	
Newburg	458	

Table 7-8. Location of Coal Burning Steam-Electric(4382) Utility Plants (1969) (continued)

State and City	Coal Burned in 1969, 1000 Tons	
INDIANA (Continued)		
Evansville	295	
Anderson	-	
Crawf'dsv'le	87	
Fort Wayne	76	
Frankfort	74	
Huntingsburg	8	
Jasper	45	
Logansport	83	
Peru	58	
Richmond	53	
Richmond	141	
Washington	58	
TOTAL INDIANA		22,592
IOWA		
Dubuque	101	
Clinton	513	
Lansing	121	
Boone	9	
Iowa Falls	1	
Cedar Rapids	493	
Marshalltown	155	
Iowana	304	
C'cil Bluffs	172	
Des Moines	347	
Carroll	3	
Charles City	5	
Eagle Grove	0.6	
Storm Lake	2	
Sioux City	14	
Waterloo	94	
Salix	172	
Eddyville	227	
Burlington	519	
Ames	20	
Cedar Falls	26	
Mt. Pleasant	22	
Muscatine	112	
Pella	37	
Sibley	5	
Webster City	11	
Humboldt	22	
Spencer	37	
Montpelier	121	
Creston	1	
TOTAL IOWA		3,667
KANSAS		
Riverton	19	
Parsons	1	
Lawrence	73	
Tecumseh	60	
Kansas City	168	
TOTAL KANSAS		321
KENTUCKY		
Louisa	1,094	
Bergen	489	
Carrollton	638	
Pineville	49	
Tyrone	98	
Louisville	2,210	
Henderson	84	
Owensboro	497	
Drakesboro	3,858	
Paducah	4,472	
Sebree	242	
Hawesville	57	
KENTUCKY (Continued)		
Burnside	421	
Ford	272	
TOTAL KENTUCKY		14,481
LOUISIANA		
TOTAL LOUISIANA		0
MASSACHUSETTS		
Holyoke	398	
Worcester	63	
New Bedford	3	
Somerset	730	
Salem	243	
Springfield	20	
W. Springfield	446	
TOTAL MASSACHUSETTS		1,903
MARYLAND		
Baltimore	3,451	
Vienna	243	
Cumberland	49	
Williamsport	389	
Chalk Point	1,122	
Dickerson	1,464	
Hagerstown	89	
TOTAL MARYLAND		6,807
MICHIGAN		
West Olive	1,349	
Muskegon	1,139	
Battle Creek	39	
Kalamazoo	31	
Essexville	1,385	
Comstock	151	
Milwaukee	125	
Essexville	1,357	
Grand Rapids	26	
Erie	955	
Detroit	2,113	
Marysville	684	
Wyandotte	26	
River Rouge	1,994	
E. China Twp.	4,484	
Trenton	2,425	
Wyandotte	67	
Harbor Beach	234	
Marquette	508	
Escanaba	77	
L'anse	26	
Coldwater	34	
Gladstone	13	
Grand Haven	69	
Holland	81	
Lansing	546	
Traverse City	144	
Wyandotte	63	
Boyne City	108	
TOTAL MICHIGAN		20,253
MINNESOTA		
Sherburn	19	
Aurora	336	
Cohasset	486	
Duluth	203	
Minneapolis	1,301	
St. Paul	505	

Table 7-8. Location of Coal Burning Steam-Electric Utility Plants (1969) (continued)(4382)

State and City	Coal Burned in 1969, 1000 Tons	
MINNESOTA (Continued)		
Granite Falls	63	
Red Wing	28	
St. Cloud	17	
Mankato	21	
Winona	34	
Oak Part Hts.	1,207	
Crookston	19	
Fergus Falls	622	
Ortonville	70	
Alexandria	5	
Austin	15	
Detroit Lakes	3	
Fairmont	6	
Hibbing	45	
Litchfield	4	
Moorhead	2	
New Ulm	12	
Rochester	61	
Sleepy Eye	4	
Springfield	2	
Two Harbors	6	
Virginia	52	
Willmar	15	
Worthington	7	
Elk River	22	
TOTAL MINNESOTA		5,192
MISSISSIPPI		
Gulfport	548	
TOTAL MISSISSIPPI		548
MISSOURI		
Montrose	1,725	
Kansas City	389	
Jefferson City	-	
Mexico	49	
Sedalia	-	
Clinton	-	
Pleasant Hill	-	
Sibley	413	
St. Joseph	39	
St. Louis	2,468	
West Alton	2,079	
Chillicothe	45	
Columbia	137	
Fulton	25	
Hannibal	42	
Independence	23	
Macon	1	
Marshall	2	
Poplar Bluff	0.6	
Springfield	28	
Randolph Co.	1,166	
Chamois	153	
Missouri City	75	
TOTAL MISSOURI	8,860	
MONTANA		
Sidney	306	
Billings	283	
TOTAL MONTANA		589
NEBRASKA		
Alliance	4	
Fremont	7	
Fremont	8	
Lincoln	2	
Hallam	168	
Lincoln	10	

State and City	Coal Burned in 1969, 1000 Tons	
NEBRASKA (Continued)		
Bellevue	89	
Omaha	59	
TOTAL NEBRASKA		885
NEW HAMPSHIRE		
Bow	934	
TOTAL NEW HAMPSHIRE		934
NEW JERSEY		
Penns Grove	128	
Beesleys Pt.	757	
Atlantic City	142	
Sayerville	584	
Holland	341	
Ridgeland	985	
Jersey City	287	
Hamilton Twp	926	
Vineland	136	
TOTAL NEW JERSEY		4,286
NEW MEXICO		
Farmington	2,778	
Raton	19	
TOTAL NEW MEXICO		2,797
NEW YORK		
Rosetown	995	
New York City Area	3,866	
Union	358	
Torry	425	
E. Corning	241	
Brainbridge	129	
Lansing	798	
Bethlehem	939	
Dunkirk	1,350	
Tonawanda	1,600	
Oswego	823	
Tompkins Cove	367	
Rochester	297	
Greece	574	
Jamestown	121	
TOTAL NEW YORK		12,883
NEVADA		
Moapa	631	
TOTAL NEVADA		631
NORTH DAKOTA		
Beulah	66 [49]	
Mandan	463 [49]	
Minot	18	
Fargo	81	
Grand Forks	49	
Devils Lake	56 [49]	
Jamestown	49 [49]	
Wahpeton	8 [49]	
Valley City	23	
Stanton	1,184	
Velva	86	
Grand Forks	4	
Stanton	807	
TOTAL NORTH DAKOTA		2,894
NORTH CAROLINA		
Moncure	969	
Goldsboro	922	

Table 7-8. Location of Coal Burning Steam-Electric(4382) Utility Plants (1969) (continued)

State and City	Coal Burned in 1969, 1000 Tons	
NORTH CAROLINA (Continued)		
Ruxboro	2,213	
Ashville	546	
Wilmington	536	
Lumberton	268	
Belmont	3,074	
Spencer	1,243	
Cliffside	601	
Draper	778	
Terrell	3,311	
Mount Holly	1,746	
Greenville	1	
Kinston	17	
Chapel Hill	22	
TOTAL NORTH CAROLINA		16,247
OHIO		
New Richmond	2,556	
North Bend	1,019	
Ashtabula	1,018	
Avon Lake	1,427	
Eastlake	1,811	
Cleveland	1,685	
Conesville	1,275	
Columbus	282	
Athens	631	
Columbus	93	
S. Dayton	852	
Dayton	1,026	
Miamisburg	-	
Dilles Bottom	1,247	
Lorain	305	
Akron	203	
Springfield	86	
Warren	-	
Niles	570	
Stratton	3,539	
Toronto	470	
Brilliant	2,996	
Beverly	3,630	
Philo	962	
Brilliant	569	
Bluffton	56	
Cheshire	2,894	
Toledo	361	
Oregon	1,497	
Toledo	-	
Celina	37	
Columbus	82	
Dover	40	
E. Palestine	24	
Hamilton	161	
Martins Ferry	37	
Napoleon	31	
Norwalk	41	
Orrville	62	
Painesville	65	
Piqua	93	
Reading	31	
St. Marys	25	
Shelby	38	
Troy	65	
TOTAL OHIO		33,892
OKLAHOMA		
Oklahoma City	1	
Ponca City	0.1	
TOTAL OKLAHOMA		1
PENNSYLVANIA		
Springdale	765	
Elrama	1,541	
South Heights	1,365	
Brunot Island	559	
Middletown	199	
Reading	860	
Portland	1,055	
Erie	351	
Saxton	119	
Seward	601	
Shawville	1,783	
Warren	236	
Williamsburg	116	
Homer City	311	
W. Pittsburgh	1,062	
York Haven	2,294	
Hauto	9	
Holtwood	502	
Martins Creek	855	
Pittston	377	
Sunbury	1,395	
Plum Creek Twp	3,345	
Philadelphia Area	3,476	
Reesedale	1,053	
Milesburg	160	
Courtney	1,218	
Springdale	752	
Masontown	26	
Chambersburg	24	
Lansdale	42	
Quakertown	20	
TOTAL PENNSYLVANIA		26,471
SOUTH CAROLINA		
Hartsville	426	
Chappels	50	
Pelzer	1,001	
Duncan	41	
Canadys	753	
Parr	76	
Irmo	430	
Beech Island	269	
Conway	540	
Moncks Corner	50	
TOTAL SOUTH CAROLINA		3,636
SOUTH DAKOTA		
Rapid City	94	
Lead	97	
Mobridge	19	
Sioux Falls	26	
Aberdeen	18	
Mitchell	19	
Watertown	4	
TOTAL SOUTH DAKOTA		277
TENNESSEE		
Memphis	1,212	
Oak Ridge	1,556	
Gallatin	2,939	
Johnsonville	1,892	
Johnsonville	1,650	
Kingston	4,030	
Rogerville	1,798	
TOTAL TENNESSEE		15,077

Table 7-8. Location of Coal Burning Steam-Electric[(4382)] Utility Plants (1969) (continued)

State and City	Coal Burned in 1969, 1000 Tons	
TEXAS		
Houston	-	
TOTAL TEXAS		0
UTAH		
Cedar City	7	
Castle Gate	351	
Orem	0.2	
Provo	17	
TOTAL UTAH		375
WEST VIRGINIA		
Cabin Creek	432	
Glasgow	1,221	
Graham	2,651	
Power	629	
Albright	753	
Morgantown	2,889	
Rivesville	544	
St. Marys	771	
Captina	1,681	
Albright	304	
Mt. Storm	2,679	
TOTAL WEST VIRGINIA		14,554
WISCONSIN		
Ashland	98	
Madison	119	
La Crosse	52	
Superior	24	
Milwaukee	28	
St. Francis	43	
Oak Creek	1,084	
Port Washington	857	
Oak Creek	2,507	
Milwaukee	519	
Appleton	-	
Beloit	63	
Sheboygan	313	
Sheboygan	28	
Cassville	632	
Beloit	440	
Rothchild	1,059	
Green Bay	177	
Manitowoc	115	
Marshfield	77	
Menasha	41	
Richland Ctr.	7	
Alma	612	
Genoa	10	
Genoa	385	
Cassville	135	
TOTAL WISCONSIN		9,425
WYOMING		
Osage	231	
Gillette	104	
Sheridan	32	
Glen Rock	1,489	
Kemmerer	1,216	
TOTAL WYOMING		3,072
VERMONT		
Burlington	37	
TOTAL VERMONT		37

State and City	Coal Burned in 1969, 1000 Tons	
VIRGINIA		
Carbo	1,990	
Glen Lyn	1,000	
Riverton	71	
Alexandria	1,062	
Bremo Bluff	546	
Chester	1,634	
Portsmouth	353	
Dumfries	433	
Norfolk	132	
Richmond	113	
Yorktown	559	
Danville	36	
TOTAL VIRGINIA		7,929
TOTAL UNITED STATES[(a)]		306,438

(a) Does not include all coal burning steam-electric plants. Estimated U.S. total for 1970 for all such plants is 333 million tons.

7.2.5 Hydrogen Fluoride Production Plant Locations

The locations and production capacity of manufacturers of hydrogen fluoride are listed in Table 7-9.

7.2.6 Clay Products Plant Locations

Producers of clay products number about 1200 in the USA (Department of Commerce 1967, Census of Manufacturers). Table 7-10 lists the quantities of clay products manufactured by processes involving heating or firing at temperatures above 1800°F. Because of the widespread availability of clay and the diverse use of clay products, it is assumed that the ratio of high temperature to low temperature clay products is constant for each state. This allows calculation of the quantity of clay fired on a state by state basis. The result of this calculation is shown in Table 7-11. The "clay products" industry covers the manufacture of pottery and stoneware; refractories; heavy clay products; architectural terra cotta; lightweight aggregates; and Portland and other hydraulic cements.

7.2.7 Manufacture of Glass Products

Glass container and fiber plant locations are listed in Table 7-12.

7.2.8 Manufacturers of Enamel Frits

Manufacturers of enamels frits are a rather small group; their locations are listed in Table 7-13.

7.2.9 Nonferrous Metal Smelters

Tables 7-14, 7-15 and 7-16 list plant locations, company names, and capacities for copper, lead and zinc smelters. It should be noted that listed capacities are normally higher than actual production rates, which are dependent upon market conditions.

Table 7-9. Plant Capacities for Hydrogen Fluoride Production(4274)

Location	Annual Capacity Tons
California	
Bay Point	12,000
Delaware	
North Claymont	25,000
Illinois	
Joliet	13,000
Kentucky	
Calvert City	25,000
Louisiana	
Baton Rouge	15,000
Geismar	40,000
Gramercy	30,000
New Jersey	
Deepwater	90,000
Paulsboro	11,000
Ohio	
Cleveland	12,000
Texas	
Houston	18,000
La Porte	75,000
Point Comfort	45,000
West Virginia	
Nitro	20,000

Table 7-10. Clay Sold or Used by Producers in the United States in 1968, by Kind(4278) (thousands of short tons)

Uses	Kaolin	Ball Clay	Fire Clay and Stoneware Clay	Bentonite	Miscellaneous Clay Including Slip Clay	Total
Pottery and stoneware:						
Whiteware, etc....................	112	282	----	---	------	394
Stoneware, art pottery, flowerpots, and glaze slip..................	---	---	59	---	60	120
Floor and wall tile...............	52	143	329	---	53	577
Refractories:						
Firebrick and block................	398	---	2772	---	------	3,227
Bauxite, high-alumina brick........	---	---	18	---	------	18
Fire-clay mortar..................	---	---	114	---	------	114
Clay crucibles....................	---	---	----	---	------	------
Glass refractories................	---	---	----	---	------	------
Foundries and steelworks..........	---	---	485	745	------	1,234
Zinc retorts......................	---	---	----	---	------	------
Saggers, pins, stilts, and wads....	---	---	----	---	------	------
Other refractories................	70	114	341	---	52	515
Heavy clay products:						
Building brick, paving brick, draintile, sewer pipe, kindred products..........................	---	---	3813	---	19,873	23,686
Architectural terra cotta..........	---	---	----	---	------	------
Lightweight aggregates.............	---	---	----	---	9,280	9,280
Portland and other hydraulic cements	63	---	----	---	11,222	11,284

Table 7-11. Fired Clays Sold or Used(4278)
(thousands of short tons)

State	Kaolin	Fire Clay	Bentonite	Miscellaneous Types	Totals
Alabama		560.8		919.4	1480.2
Arizona		0.1	28.5	22.1	50.3
Arkansas				342.0	342.0
California	6.2	506.3	32.1	968.9	1513.5
Colorado		228.4	1.8	168.3	398.5
Connecticut				87.8	87.8
Delaware				5.4	5.4
Georgia	842.5			733.9	1581.4
Idaho				5.4	5.4
Illinois		234.3		936.0	1170.3
Indiana		167.5		616.1	783.6
Iowa				568.8	568.8
Kansas		144.9		348.3	493.2
Kentucky		186.3		460.4	646.7
Louisiana				388.5	388.5
Maine				18.9	18.9
Maryland				485.1	485.1
Massachusetts				115.6	115.6
Michigan				1169.3	1169.3
Minnesota				105.3	105.3
Mississippi			269.2	478.4	747.6
Missouri		1011.0		616.1	1627.1
Montana				13.5	13.5
Nebraska				66.6	66.6
New Hampshire				18.5	18.5
New Jersey		79.9		120.1	200.0
New Mexico		1.9		28.8	30.7
New York				753.8	753.8
North Carolina	10.6(1)			1489.5	1500.1
Ohio		1907.3		1231.6	3138.9
Oklahoma		0.4		326.7	327.1
Oregon			1.0	95.4	96.4
Pennsylvania		1352.8		724.5	2077.3
South Carolina	147.2			609.8	757.0
Tennessee				516.9	516.9
Texas		727.9	89.8	1290.2	2007.9
Utah		11.3	1.0	64.3	76.6
Virginia				657.9	657.9
Washington				63.0	63.0
West Virginia				87.3	87.3
Wisconsin				7.7	7.7
Wyoming			1724.6		1724.6
Others	101.6	533.4	217.8	249.6	1102.4

(1) North Carolina and Florida uses combined

Table 7-12. Locations of Manufacturers of Glass Products(4277)

Container Plants		Fiber Plants	
Alabama	1	California	3
California	15	Florida	1
Connecticut	1	Kentucky	1
Florida	3	Kansas	3
Georgia	2	New Jersey	4
Illinois	9	North Carolina	1
Indiana	10	Ohio	4
Louisiana	3	Rhode Island	1
Maryland	3	Pennsylvania	2
Michigan	1	South Carolina	1
Minnesota	1	Texas	3
Mississippi	4	Total Production in 1967	305,000 tons
New Jersey	9		
New York	5		
North Carolina	2		
Ohio	4		
Oklahoma	6		
Oregon	1		
Pennsylvania	14		
South Carolina	1		
Texas	5		
Washington	1		
West Virginia	4		
Wisconsin	1		
Total Production in 1967	8,865,900 tons		

Table 7-13. Locations of Manufacturers of Enamel Frits(4280)

Location	Number
California	
Los Angeles	1
Illinois	
Chicago	2
Indiana	
Frankfort	1
Kentucky	
Louisville	1
Maryland	
Baltimore	1
Michigan	
Muskegon	1
New York	
Buffalo	1
Rochester	1
Ohio	
Cleveland	1
Marysville	1
Salem	1
Pennsylvania	
Ford City	1
Pittsburgh	1
Scranton	1
Tennessee	
Nashville	1
Wisconsin	
Kohler	1
Milwaukee	1

Table 7-14. Primary Copper Smelter Plant Locations and Capacities

State and City	Company	Charge Capacity 1000 tons/year (a)
Texas		
El Paso	Asarco (c)	420
Arizona		
Hoyden	Kennecott Copper Co.	420
Hoyden	Asarco	420
Miami	Inspiration Consolidated Copper Co.	450
Superior	Magma Copper Co.	150
San Manuel	Magma Copper Co.	403
Douglas	Phelps Dodge Corp.	1250
Morenci	Phelps Dodge Corp.	900
Ajo	Phelps Dodge Corp.	300
Nevada		
Mc Gill	Kennecott Copper Co.	400
New Mexico		
Hurley	Kennecott Copper Co.	400
Utah		
Garfield	Kennecott Copper Co.	1000
Montana		
Anaconda	Anaconda Co.	1000
Washington		
Tacoma	Asarco	600
Tennessee		
Copperhill	Tennessee Corp.	90
Michigan		
White Pine	White Pine Copper Co.	90 (b)
Total capacity (excl. White Pine Copper Co.)		8203

(a) Tonnage capacity for smelting materials that yield a product.

(b) Thousands of tons of copper.

(c) American Smelting and Refining Co.

Table 7-15. Primary Zinc Smelter Plant Locations and Capacities

State and City	Company	Zinc Capacity 1000 tons/year
Texas		
Corpus Christi	Asarco	108
Amarillo	Asarco	54
Dumas	American Zinc	57
Oklahoma		
Blackwell	Blackwell Zinc Co.	90
Henryetta	Eagle-Picher Co.	54
Bartlesville	National Zinc Co.	65
Idaho		
Kellogg	Bunker-Hill Co.	110
Montana		
Great Falls	Anaconda Co.	162
Anaconda	Anaconda Co.	87
Illinois		
Monsanto	American Zinc Co.	84
Depue	New Jersey Zinc Co.	57
West Virginia		
Meadowbrook	Matthiessin and Hegeler	50
Pennsylvania		
Palmerton	New Jersey Zinc Co.	110
Josephtown	St. Joseph Lead Co.	175
Total Capacity		1263

Table 7-16. Primary Lead Smelter Plant Locations and Capacities

State and City	Company	Capacity 1000 Tons/Year
Texas		
El Paso	Asarco	360
Utah		
Tooele	International Smelting and Refining Co.	300
Idaho		
Bradley	Bunker Hill Co.	390
Montana		
East Helena	Asarco	360
California		
Selby	Asarco	192
Missouri		
Glover	Asarco	180
Buick	Missouri Lead Co.	300
Herculaneum	St. Joseph Lead Co.	600
Total Capacity		2682

7.3 PHYSICOCHEMICAL PARAMETERS OF EVOLVED FLOURIDES

The physical and chemical properties of the fluoride compounds present as both major and minor fluoride-containing components of process effluent streams are prescribed in the following tables.

This section contains its own separate bibliography, covering the references used as sources for the data presented.

PHYSICAL AND CHEMICAL PROPERTIES OF FLUORIDE COMPOUNDS PRESENT IN PROCESS EFFLUENT STREAMS

Compound	Page
AlF_3	7-51
BF_3	7-52
BaF_2	7-53
$BaSiF_6$	7-54
CaF_2	7-55
F_2	7-56
FeF_2	7-57
FeF_3	7-57
HF	7-58
H_2SiF_6	7-65
KF	7-71
K_2SiF_6	7-76
MgF_2	7-77
NH_4HF_2	7-78
$(NH_4)_2SiF_6$	7-78
NH_4F	7-79
Na_3AlF_6	7-80
NaF	7-81
Na_2SiF_6	7-83
SiF_4	7-86
UF_6	7-88

SUPPLEMENTARY SOLUBILITY DATA

Compound	Page
CaF_2	7-90
H_2SiF_6	7-91
KF	7-92
K_2SiF_6	7-96
NH_4F	7-97
Na_3AlF_6	7-99
NaF	7-100
Na_2SiF_6	7-102
Bibliography	7-104

AlF_3

MW _ 83.97

MP _ Sublimes at 1291°C

Density _ 2.88 2 g/cm^3

Vapor Pressure Data

Temperature °C	Pressure mm Hg
1098	16.4
1123	33.4
1181	130.7
1218	254.7
1275	553.9
1294	767

Solubility of AlF_3 in H_2O at 25°C _ 0.56 g/100g H_2O

Solubility of AlF_3 in Aqueous Solutions of HF at 25°C

Gms. per 100 gms. sat. sol.		Solid Phase	Gms. per 100 gms. sat. sol.		Solid Phase	Gms Per 100 gms. sat. sol.		Solid Phase
HF	AlF_3		HF	AlF_3		HF	AlF_3	
0.0	0.55	$AlF_3.H_2O$	27.64	19.68	1.3.6	39.01	16.08	1.3.3
0.77	0.39	"	28.90	14.84	"	41.00	14.03	"
2.00	1.56	"	30.66	12.52	"	42.45	12.96	"
4.96	2.74	"	31.07	13.42	"	46.88	10.43	"
10.44	5.37	"	31.90	13.21	"	51.80	7.15	"
17.77	9.58	"	34.07	13.63	"	54.03	6.18	"
21.08	16.63	"	36.13	13.44	"	57.57	5.04	"
22.94	19.00	"	37.08	14.18	"	60.83	4.00	"
26.30	19.68	1.3.6	37.81	17.07	"	62.73	3.53	"

1.3.6 = $AlF_3.3HF.6H_2O$; 1.3.3 = $AlF_3.3HF.3H_2O$

Heat of formation at 25°C _ -355.7 Kcal/g mole

Heat of Sublimation at 1291°C _ 73.0 ± .4 Kcal/g mole

Entropy at 298°K _ 23 eu

Critical Temperature _ 2424°C

BF_3

MW - 67.82

MP - -127.1°C

BP - -100.3°C

Sp.Vol. - 5.6 ft^3/lb. @ 70°F=1 atm

Density at B.P. - 1.6 g/cm^3

Solubility in H_2O at 0°C and 762 mm Hg - 322 g/100g H_2O

Vapor Pressure Data:

Temperature °C	Pressure
-127.3	69.8 mm. Hg
-120.5	139.7 mm.Hg
-112.4	291.4 mm.Hg
-110.0	355.7 mm.Hg
-105.3	514.3 mm.Hg
-100.3	760 mm.Hg
-73.3	4.61 atm.
-63.3	7.50 atm.
-54.4	10.00 atm.
-49.25	13.8 atm.
-29.96	27.9 atm.
-12.25 (C.T.)	49.0 atm.

Heat Capacity (gas):

100°K - 6.98 cal/g mole -°K

300°K -11.42 "

500°K -14.39 "

1000°K -17.94 "

Heat of Fusion @ -128°C - 101.Kcal/g mole

Heat of Vaporization - 4.06 Kcal/g mole

Heat of Formation at 298°K- -265.4 Kcal/g mole

Entropy at 298°K - 60.70 eu

Critical Temperature - -12.25 ± .03°C

Critical Pressure - 49.2 ± .1 atm.

Ba SiF_6

MW - 279.41

MP - Dissociation starts at 327°C

Density - 4.29 g/cm^3

Solubility of $BaSiF_6$ in Water

t°C	Gms. $BaSiF_6$ per 100cc. sat.sol.
0	0.015
16	0.019
25	0.025
35	0.028

t°C	Gms. $BaSiF_6$ per 100 gms. sat. sol.
45	0.031
55	0.035
78	0.044

Note - pH ≐ 4.4 at a concentration of 0.27 grams $BaSiF_6$/100 ml H_2O.

Dissociation Pressure Data:

Temperature °C	Pressure mm Hg
416	29
443	63
476	247
481	303
487	360
498	537

For the reaction $BaSiF_6\ (S) \rightarrow BaF_2(S) + SiF_4(g)$

Heat of Dissociation- -43 Kcal/g mole

Heat of Formation (solid) at 298°K- - 691.6 Kcal/ g mole

BaF_2

MW - 175.3

MP - 1327°C

BP - 1927°C

Density - 4.89 g/cm^3

Solubility of BaF_2 in water

1.59 g/liter of sat. solution at 10°C

1.61 g/liter of sat. solution at 20°C

1.62 g/liter of sat. solution at 30°C

Note - at a concentration of 1.21 g BaF_2/ liter of sat. solution pH = 4.4

Solubility of BaF_2 in Hydrochloric Acid

Normality of HCl at beginning	Gm. Moles BaF_2 Dissolved per liter.	pH of Sat sol.
0.01	0.0123	3.0
0.10	0.0414	1.6
1.0	0.1140	0.11

Heat of Formation (Solid) at 298°K - -296.9 Kcal/g mole

Heat of Fusion - 3.0 Kcal/g mole

Heat of Vaporization - 83.0 Kcal/g mole

Entropy at 298°K - 23.0 eu.

CaF_2

MW - 78.08

MP - 1418°C

BP - 2513°C

Density - 3.18 g/cm^3

Solubility of CaF_2 in Water

t°C	Gms. CaF_2 per liter sat. sol.	
0	0.013	(flurospar)
15	0.015	(fluorspar)
18	0.016	
18	0.018	
18	0.015	(calcined)
25	0.018	
25	0.016	(fluorspar)
25	0.040	(pH = 6.4)
40	0.017	(fluorspar)

Solubility of CaF_2 in Acetic Acid

	Gms. CaF_2 dissolved per 100 cc. in aqucous		
t°C	0.5 Normal CH_3COOH.	1.0 Normal CH_3COOH.	2.0 Normal CH_3COOH.
40	0.0153	0.0175	0.0192
60	0.0178	0.0203	0.0229
80	0.0206	0.0237	0.0267
100	0.0229	0.0264	0.0300

Solubility of CaF_2 in Hydrochloric Acid at 25°C

Normality of aq. HCl	Gm. moles CaF_2 Dissolved per liter	pH of sat. sol.
0.01	0.00087	2.02
0.10	0.0053	1.05
1.00	0.0280	0.04

Heat of Formation (Solid) at 298°K - -290.3 Kcal/g mole

Heat of Fusion - 7.10 Kcal/g mole

Heat of Vaporzation - 83.0 Kcal/g mole

Entropy at 298°K - 16.4 eu.

F_2

MW - 38.00

MP --219.62°C

BP.--188.14°C

Spec. Volume @ 70°F, 1 atm. - 10.2 ft^3/lb.

Density (liquid)@ BP.- 1.108 g/cm^3

Density (gas) @ 0°C, 1 atm - 1.696 g/liter

Viscosity (gas @ 0°C, 1 atm) - 0.0218 cp.

Vapor Pressure Data:

Critical temperature - 144°K

Cirtical Pressure - 55 atm.

Temperature °C	Pressure m m Hg
-223	1
-214.1	10
-207.7	40
-202.7	100
-193.2	400
-187.9	760

Entropy at 298°K - 48.6 eu

Heat of Fusion at M.P. - 372 Cal/g mole

Heat of Vaporization at B.P. - 1,564±3 cal/g mole

Heat Capacity Data (gas)

300°K - 7.45 Cal/g mole °K

500°K - 8.05 "

800°K - 8.62 "

1200°K - 8.99 "

FeF_2

MW - 93.84
MP - Sublimes at ~ 1100°C
Density - 4.09 g/cm^3
Heat of Formation at 298°K - -154.2 Kcal/g mole

FeF_3

MW - 112.84
MP - Sublimes at ~ 1000°C
Density - 3.52 g/cm^3

HF

MW - 20.01
MP - -83°C
BP - 19.5°C
Spec. Vol. @ 70°F, 1 atm. - 17 ft^3/lb
Density of liquid @ 0°C - 1.0015 g/cm^3
Viscosity @ 0°C - 0.25 cp

Infinite solubility in H_2O and Alcohol

Viscosity of Liquid HF

t in °C	Pure HF Centistokes C	 centipoise cp	Commerical HF C	93.4% HF 0.5% H_2O C_2H_5OH 6.1 C
-68.75	0.780	0.914	0.893	----
-62.5	.668	.772	.797	0.983
-56.25	.585	.666	.720	.878
-50.0	.507	.570	.645	.788
-43.75	.450	.498	.579	.720
-37.5	.397	.434	.525	.668
-31.25	.360	.387	.472	.615
-25.0	.330	.350	.420	.575
-18.75	.306	.320	.377	.533
-12.5	.285	.296	.353	.499
- 6.25	.270	.274	.330	.470
0.0	.256	.256	.310	.447
+ 6.25	.243	.240	----	----

Boiling Point of HF-H_2O Mixtures at 760 mm Hg

G. Mole H_2O per 1000 g. HF	Mole % HF	B.p. °C
	0	100.00
667	6.98	101.45
384	11.52	102.83
204	19.70	106.02
164	23.32	107.55
10.93	82.07	46.05
6.01	89.28	32.12
5.64	89.87	28.3
4.72	91.38	29.5
4.54	91.80	28.95

HF (Cont)

154	24.46	108.60	4.0	92.06	27.92
138	26.63	108.80	3.5	93.04	26.89
113	30.62	110.93	3.0	94.03	25.90
100	33.26	111.35	2.5	95.02	24.89
73	40.48	111.10	2.0	96.01	23.88
66.1	43.08	109.90	1.5	97.00	22.87
53.8	48.19	106.00	1.0	98.00	21.86
45.0	52.66	100.6	0.75	98.50	21.14
39.7	55.78	85.5	0.5	99.00	20.81
35.0	58.86	79.25	0.4	99.20	20.58
31.3	61.51	86.55	0.3	99.40	20.35
25.7	66.09	74.65	0.2	99.64	20.10
24.7	66.99	68.55	0.1	99.82	19.84
20.85	70.39	62.35	0.005	99.91	19.70
18.05	73.48	58.55	0	100	19.54
12.88	79.55	44.55			

Composition Wt% HF					
Liquid	Vapor	B.p. °C	Liquid	Vapor	B.p. °C
5.47	0.87	101.6	42.2	50.1	111.4
10.1	2.03	102.8	47.0	65.7	108.7
20.6	7.06	106.8	49.2		106.8
24.7	11.6	108.4	52.9	82.6	101.7
30.1	19.4	110.3	54.8	87.4	98.9
36.2	32.8	111.7	58.6	92.9	90.9
36.8	34.4	112.0	60.7	97.3	86.6
37.6	36.4	112.1	64.1	98.0	79.0
38.22	38.15	112.3	66.2	98.7	74.6
38.27	38.26	112.4	72.0	98.8	61.6
39.2	41.1	112.1	81.4	99.3	45.1
			89.0	99.5	33.5

HF (Cont)

Freezing Points of $HF-H_2O$ mixtures

t°C	Gm. Moles HF per 100 gm. Moles $HF+H_2O$	Solid Phase	t°C	Gm. Moles HF per 100 gm. Moles. $HF+H_2O$	Solid Phase
-0.9	0.777	Ice	-75.4	69.8	$2HF.H_2O$
-6.3	5.64	"	-75.7	71.0	"
-9.8	8.09	"	-81.7	74.3	"
-23.0	15.65	"	-91.1	76.2	"
-41.4	21.6	"	-101.3	77.6	" $+4HF.H_2O$
-60.0	26.5	"	-100.7	78.6	$4HF.H_2O$
-70.1	27.6	" $+HF.H_2O$	-100.3	79.6	"
-62.7	30.7	$HF.H_2O$	-100.2	80.0	"
-59.4	32.1	"	-100.6	81.7	"
-48.9	37.1	"	-105.4	86.4	"
-43.5	40.3	"	-110.8	88.3	" + HF
-36.1	47.8	"	-106.9	89.4	HF
-35.3	50.0	"	-99.7	91.3	"
-35.8	51.5	"	-93.6	93.9	"
-41.5	57.5	"	-88.9	96.1	"
-51.0	62.7	"	-86.9	97.4	"
-68.3	67.5	"	-85.4	98.2	"
-75.1	68.5	" $+2HF.H_2O$	-82.9	100.00	"

Solubility of HF in Benzene

t°C of the Liquid HF from which its vapor was conducted	Gm. Moles HF dissolved per 100 gm. Mole $HF+C_6H_6$				
	20°	30°	40°	50°	60°
-77	2.48	2.03	1.58	1.12	0.71
-18	3.85	3.15	2.44	1.73	1.02
0	4.32	3.55	2.75	1.96	1.17
b.pt.	6.73	5.48	4.22	2.98	1.80

Degree of Association - Gaseons HF

Temp. °K =	234	252	263	274	278	282	285	289
$(HF)_n$;n =	4.37	4.08	3.715	3.38	3.465	3.215	3.475	2.385

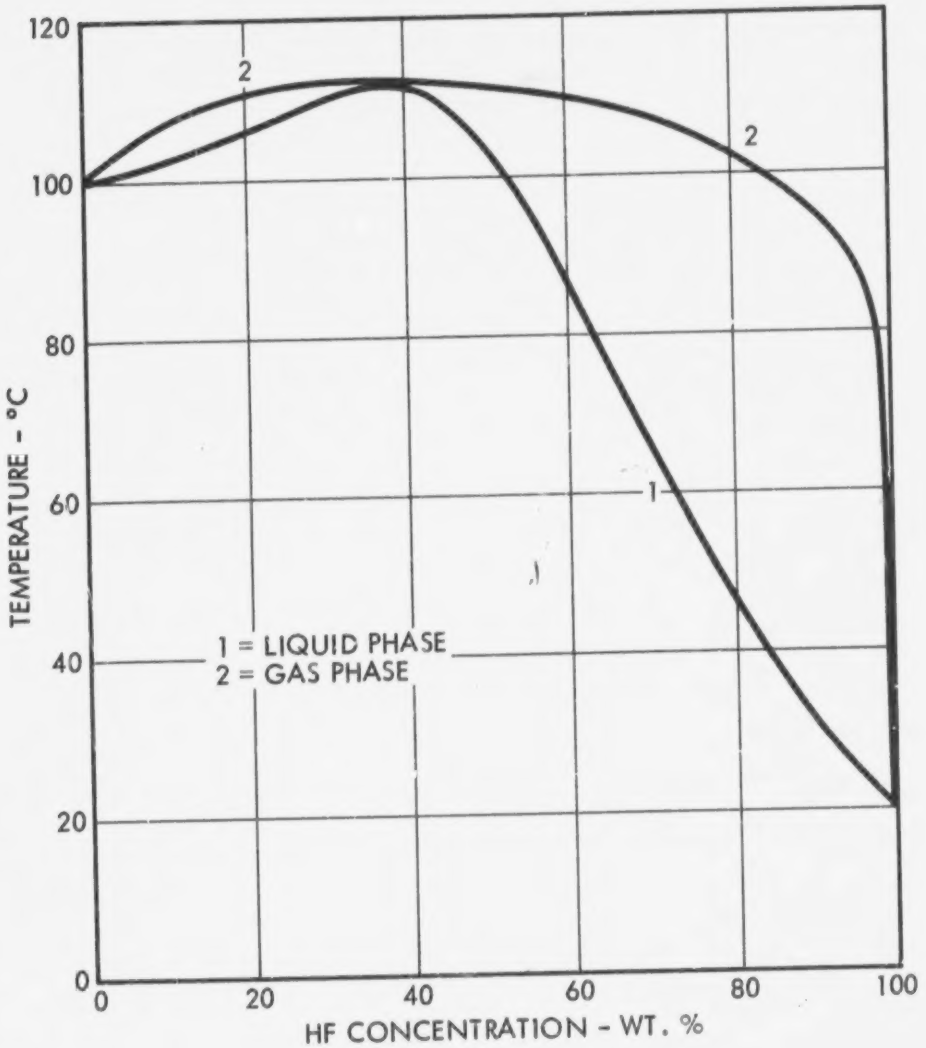
HF (Cont)

Vapor Pressure of the HF-H_2O System
(P in mm Hg)

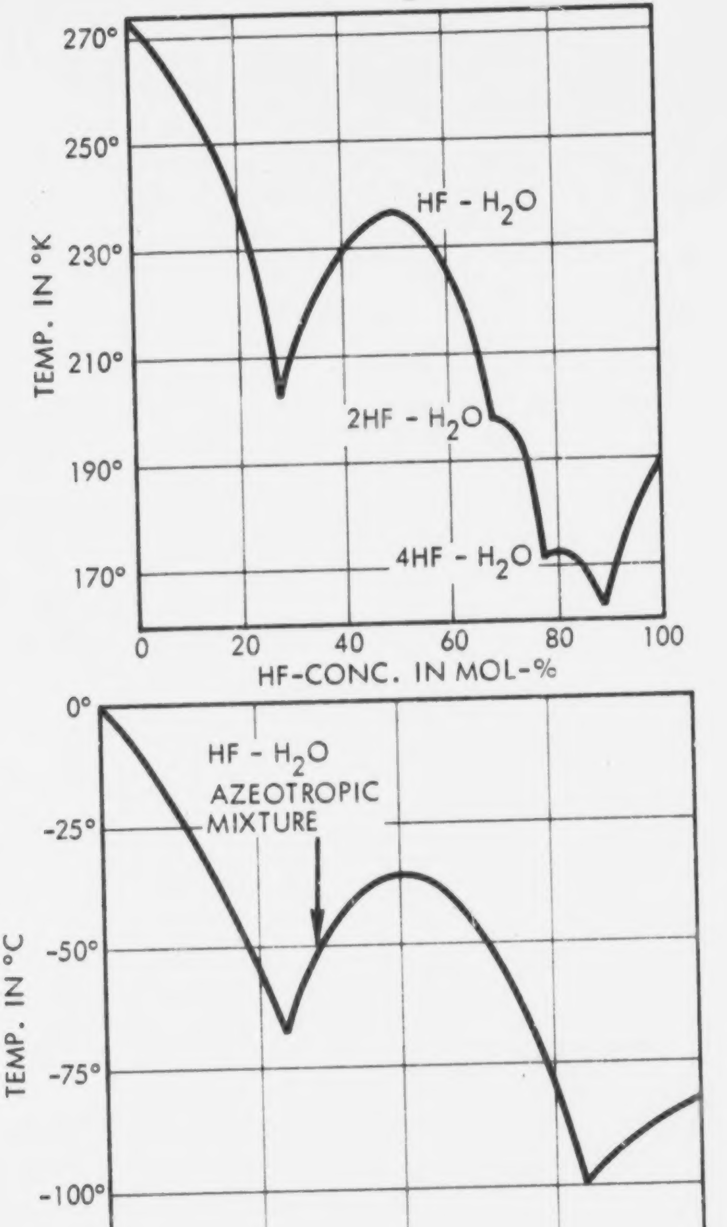
wt % HF	5.00	10.00	12.85	19.00	27.60	39.20	Temp, °C
mole % HF	4.52	9.09	11.65	17.42	25.56	36.70	
P_{HF}	----	----	----	0.53	1.37	5.59	25
P_{H_2O}	----	----	----	14.9	10.0	10.1	25
P_T*	----	----	----	15.43	11.37	15.69	25
P_{HF}	0.11	0.53	0.82	1.20	----	----	40
P_{H_2O}	49.5	44.9	43.7	39.1	----	----	40
P_T	49.61	45.93	44.52	40.30	----	----	40
P_{HF}	0.21	0.86	1.57	2.48	6.50	22.14	50
P_{H_2O}	83.0	76.9	68.6	57.6	41.0	34.0	50
P_T	83.21	77.76	70.17	60.08	47.50	56.14	50
P_{HF}	0.49	1.52	-----	4.63	10.61	----	60
P_{H_2O}	131.5	117.6	----	104.0	72.7	----	60
P_T	131.99	119.12	----	108.63	83.31	----	60
P_{HF}	1.97	3.78	6.35	9.69	24.39	----	75
P_{H_2O}	267.0	244.3	237.6	207.9	153.3	----	75
P_T	268.97	248.08	243.95	217.59	177.69	----	75

*P_T = Total system pressure in mm Hg.

HF - H_2O BOILING POINT CURVE



PHASE DIAGRAM SYSTEM
$HF - H_2O$



HF(Cont)

Solubility of HF in Octane

t°C of sat. sol. in Octane	25.1°	36.0°	45.2°	51.0°	66.3°
Moles HF per 100 moles HF + C_8H_{18}	0.338	0.276	0.235	0.194	0.170

Heat of Formation of the gas - -64.8 Kcal/g mole
at 298°K

Heat of Vaporization @ BP. - 97.5 cal/gram

Heat of Fusion @ mp. - 54.7 cal/gram

Entropy at 298°K - 41.63 eu.

Critical Temperature - 230.2°C

Heat Capacity of the gas:

100°K - 6.90 cal/g mole -°K
300°K - 6.93 "
500°K - 6.95 "
1000°K - 7.19 "
1500°K - 7.64 "

Heat capacity of the Liquid @ -3°C- 0.838 cal/gram -°K

Vapor Pressure Data:

Data below 0°C

Temperature °C	Pressure mm Hg.
-66	10
-45	40
-28	100
-2.5	400

Data above 75°F

Temperature °F	Pressure psia.
75	17.0
150	50.0
200	88.2
250	146
300	230
400	432

H_2SiF_6

MW - 144.07

Equilibrium in the H_2SiF_6-H_2O System at 720 mm Hg Pressure

% H_2SiF_6 in Solution			Distillate	
Before Distillation	After Distillation	Mean	HF/SiF_4 mole ratio	SiF_4/H_2F_2 mole ratio
10.1	11.1	10.6	5.65	0.354
11.1	11.7	11.4	3.49	0.573
14.0	16.4	15.2	1.46	1.370
16.3	20.5	18.4	1.11	1.802
23.6	27.9	25.8	0.56	3.571
30.2	31.4	30.8	0.29	6.897

Heat of Formation at 298°K - -557.2 Kcal/g mole

H_2SiF_6 (Cont)

Equilibrium in the H_2SiF_6-H_2O System

$x=H_2SiF_6.6H_2O$, $y=Si(HF_2.3H_2O)_4$, $z=H_2O$

BP °C	Weight percent of liquid phase					Weight percent of gas phase				
	HF	H_2SiF_6	x	y	z	HF	H_2SiF_6	x	y	z
104.4	0.2	24.1	40.8	2.2	57.0	0.2	2.5	3.5	1.6	94.9
107.3	.8	29.7	47.2	7.6	45.2	.2	5.3	8.3	1.6	90.1
108.1	4.4	26.0	17.8	44.0	38.2	3.3	1.4	^{2}(8.3)	3.8	87.9
108.8	.9	33.2	52.7	8.5	38.8	.2	9.7	16.0	1.7	82.3
111.4	1.9	36.2	51.5	18.9	29.6	.2	18.0	30.3	1.9	67.8
112.7	2.7	38.3	50.5	26.9	23.0	.3	25.9	43.7	2.7	53.6
113.1	5.6	33.7	23.7	56.0	20.3	5.2	12.3	A(5.0)	34.2	60.8
114.3	4.6	38.0	37.5	46.0	16.5	.1	30.7	53.4	.6	46.0
115.2	6.3	37.9	26.5	63.3	10.2	1.0	39.1	62.3	9.8	27.9
115.3	7.6	37.3	17.6	75.6	6.8	3.6	39.3	46.0	36.1	17.9
115.3	7.9	37.2	15.6	78.6	5.8	5.4	36.4	29.3	54.5	16.2
115.5	6.5	38.5	26.4	65.1	8.5	.2	46.3	79.6	2.4	18.0
115.5	8.9	37.9	10.4	88.8	.8	3.5	50.2	67.3	32.6	.1
115.7	7.9	37.0	15.0	79.0	6.0	5.4	55.1	29.7	54.3	16.0
115.7	9.1	36.7	6.7	91.3	2.0	7.8	36.1	14.3	77.6	8.1

H_2SiF_6 (Cont)

$x=Si(HF_2.3H_2O)_4$, $y=H_2F_2.4H_2O$, $z=H_2O$

BP °C	Weight percent of liquid phase					Weight percent of gas phase				
	HF	H_2SiF_6	x	y	z	HF	H_2SiF_6	x	y	z
115.9	10.8	34.2	95.0	3.6	1.4	12.8	27.4	76.1	14.5	9.4
113.5	9.8	25.8	71.7	7.5	20.8	8.6	.4	1.1	23.6	75.3
113.3	18.6	16.4	45.6	39.3	15.1	14.3	.6	1.6	39.6	58.8
110.3	30.1	0	0	84.3	15.7	19.4	0	0	54.3	45.7
110.0	25.3	5.2	14.6	66.8	18.6	17.3	.1	.3	48.4	51.3
108.4	8.3	22.7	63.1	5.6	31.3	6.0	.5	1.3	16.4	82.3
108.4	24.7	0	0	69.1	30.9	11.6	0.0	0	32.5	67.5
106.8	20.6	0	0	57.7	42.3	7.1	0	0	19.8	80.2
102.8	10.1	0	0	28.3	71.7	2.0	0	0	5.7	94.3
101.6	5.5	0	0	15.3	84.7	.9	0	0	2.4	97.6

$x=Si(HF_2.3H_2O)_4$, $y=H_2F_2.4H_2O$, $z=H_4F_4.7H_2O$

113.2	26.7	14.9	41.4	6.2	52.4	36.4	1.2	3.4	46.6	50.0
112.5	28.3	11.6	32.4	39.6	28.2	35.0	.1	.3	97.9	B(1.8)
112.4	38.3	0	0	17.6	82.4	38.3	0	0	17.9	82.1
112.3	38.2	0	0	19.2	80.8	38.1	0	0	21.5	78.5
112.1	37.6	0	0	39.1	60.9	36.4	0	0	77.6	22.4
112.0	36.8	0	0	64.7	35.3	34.4	0	0	96.4	B(3.6)
111.7	36.2	0	0	84.0	16.0	32.8	0	0	91.9	B(8.1)

H_2SiF_6 (Cont)

$x=Si(HF_2.3H_2O)_4$, $y=H_2F_2.2H_2O$, $z=H_4F_4.7H_2O$

	Weight percent of liquid phase					Weight percent of gas phase				
BP °C	HF	H_2SiF_6	x	y	z	HF	H_2SiF_6	x	y	z
115.3	12.5	33.0	91.7	0.7	7.6	18.3	23.3	64.7	A(33.1)	B(2.1)
114.9	15.6	29.8	82.8	4.6	12.6	26.9	14.1	39.2	A(20.4)	40.5
114.9	19.6	27.2	75.6	18.5	5.9	35.4	11.8	32.8	43.7	23.5
113.2	27.6	15.3	42.5	7.5	50.0	40.4	1.6	4.6	21.2	74.2
112.1	39.2	0	0	97.2	2.8	41.1	0	0	83.5	16.5
111.9	29.8	16.1	44.7	28.0	27.2	49.9	2.4	6.6	93.2	C(.2)
111.4	42.2	0	0	75.5	24.5	50.1	0	0	18.3	81.7
111.2	39.1	5.0	14.0	31.3	54.7	54.1	.4	1.1	94.7	C(4.1)
108.7	47.0	0	0	40.7	59.3	65.7	0	0	72.4	C(27.6)

$x=Si(HF_2.3H_2O)_4$, $y=H_2F_2.2H_2O$, $z=H_2F_2$

101.7	52.9	0.0	0.0	99.4	0.6	82.6	0.0	0.0	36.7	63.3
98.9	54.8	0	0	95.4	4.6	87.4	0	0	26.6	73.4
90.9	58.6	0	0	87.4	12.6	92.9	0	0	15.0	85.0
86.6	60.7	0	0	82.9	17.1	97.3	0	0	5.7	94.3
79.0	64.1	0	0	75.8	24.2	99.0	0	0	2.1	97.9
74.6	66.2	0	0	71.3	28.7	98.7	0	0	2.7	97.3
61.6	72.0	0	0	59.1	40.9	98.8	0	0	2.5	97.5
45.1	81.4	0	0	39.3	60.7	99.3	0	0	1.5	98.5
33.5	89.0	0	0	23.2	76.8	99.5	0	0	1.0	99.0

H_2SiF_6 (Cont)

$x=Si(HF_2.3H_2O)_4$, $y=H_2F_2.2H_2O$, $z=H_2SiF_6.6H_2O$

BP °C	Weight percent of liquid phase					Weight percent of gas phase				
	HF	H_2SiF_6	x	y	z	HF	H_2SiF_6	x	y	z
116.1	10.1	36.0	98.9	0.4	0.7	9.8	36.0	98.4	D(0.6)	1.0
115.6	12.9	34.4	84.9	8.4	6.7	16.8	35.4	35.1	25.1	39.8
115.4	15.4	31.6	85.7	13.0	1.3	25.6	23.4	57.8	37.6	4.6
115.2	9.3	38.1	87.1	1.1	11.8	3.6	51.8	13.4	4.4	82.2
114.8	18.6	29.0	77.2	20.7	2.1	33.7	19.9	6.2	62.9	30.9
114.2	17.3	32.9	53.0	22.8	24.2	26.7	36.8	D(16.8)	18.8	64.4
113.4	23.9	24.5	65.0	33.1	1.9	44.8	12.0	D(6.8)	72.2	21.0
104.4	37.2	16.7	.4	70.6	29.0	71.6	8.8	D(57.3)	27.2	15.5

$x=H_2F_2$, $y=H_2F_2.2H_2O$, $z=H_2SiF_6.6H_2O$

100.9	26.1	32.4	7.0	36.3	56.7	37.3	58.2	51.8	D(37.7)	10.5
100.1	36.3	20.7	5.8	58.0	36.2	74.6	13.9	73.6	2.1	24.3
95.9	33.6	26.0	10.4	44.1	45.5	57.6	36.7	65.7	D(21.0)	13.3
94.0	45.7	12.0	8.7	70.3	21.0	87.7	4.0	81.8	11.2	7.0
89.5	22.9	38.7	12.5	19.7	67.7	5.2	93.2	30.5	D(65.7)	3.8
76.2	49.2	18.6	28.9	38.5	32.6	66.6	32.2	75.1	D(22.1)	2.8
70.1	40.5	27.5	27.9	24.0	48.1	26.5	72.6	46.4	D(51.6)	2.0
67.1	60.7	9.0	34.5	49.8	15.7	92.2	2.1	87.6	8.7	3.7
63.8	54.1	16.5	35.2	35.9	28.9	63.0	35.8	72.5	D(24.7)	2.8
62.5	33.0	36.0	28.6	8.4	63.0	.6	98.4	27.6	D(70.1)	2.3
46.9	60.0	17.1	48.8	21.2	29.9	26.3	73.0	46.3	D(52.1)	1.6

H_2SiF_6 (Cont)

$x = H_2F_2$, $y = SiF_4$, $z = H_2SiF_6 \cdot 6H_2O$

BP °C	Weight percent of liquid phase					Weight percent of gas phase				
	HF	H_2SiF_6	x	y	z	HF	H_2SiF_6	x	y	z
46.6	69.6	9.3	53.9	29.8	16.3	43.3	56.2	58.7	40.1	1.2
33.7	53.1	25.3	50.2	5.5	44.3	.9	96.0	26.5	66.4	7.1
32.7	70.6	11.9	61.1	18.1	20.8	6.0	93.6	31.8	67.2	1.0
25.5	92.0	.7	84.5	14.3	1.2	77.4	21.8	83.1	15.0	1.9

A = $H_2F_2 \cdot 4H_2O$

B = H_2O

C = H_2F_2

D = SiF_4

KF

MW - 58.10

MP - 846°C

BP - 1505°C

Density = 2.85 g/cm^3

Vapor Pressure Data:

Temperature °C	Pressure mm Hg
795	1
982	10
1050	40
1137	100
1297	400
1383	760

Solubility of KF in H_2O

t°C	Gms. KF Per 100 gms. sat. sol.	Solid Phase	t°C	Gms. KF Per 100 gms. sat. sol.	Solid Phase
-3.2	5.0	Ice	0	44.30	$KF.2H_2O$
-6.5	10.0	"	17.5	47.52	"
-12.2	15.0	"	18	48.0^2	"
-19.5	20.0	"	20	48.70	"
-21.8 (Eutec.)	21.5	"+ $KF.4H_2O$	25	50.41	"
-20.0	22.7	$KF.4H_2O$	30	51.95	"
0	30.90	"	35	54.65	"
10	34.87	"	40.2	58.08	"
15	38.13	"	45	58.62	KF
17.5	41.52	"	60	58.72	"
17.7	47.7	"+ $KF.2H_2O$	80	60.01	"

KF (Cont)

Equilibrium in the KF-HF-H_2O System

At 0°C Gms. per 100 gms. sat. sol.		At 20°C Gms. per 100 gms. sat. sol.		At 40°C Gms. per 100 gms. sat. sol.		Solid Phase
KF	HF	KF	HF	KF	HF	
42.77	0.0	47.75	0.0	56.36	0.0	$KF.2H_2O$
----	---	47.80	0.27	58.50	0.30	"
44.15	0.36	47.90	0.72	59.20	1.37	$KF.2H_2O$+KF.HF
41.00	0.38	38.30	0.82	39.70	1.50	KF.HF
39.66	0.43	35.47	1.12	37.28	1.89	"
29.75	0.71	31.00	1.46	32.28	2.95	"
27.33	0.95	21.53	5.05	29.72	4.23	KF.HF
24.08	1.25	20.50	6.88	27.60	7.24	"
22.86	1.41	21.47	10.04	27.10	9.26	"
20.12	1.89	26.70	17.97	29.12	14.22	"
17.85	2.40	27.70	18.34	30.75	17.55	"
14.72	4.15	38.00	28.38	38.40	23.80	"
14.08	5.23	40.67	29.84	46.07	30.00	"
14.63	6.43	41.57	30.55	47.80	31.95	"
16.30	10.43	42.94	31.36	48.83	32.72	"
21.50	17.71	43.41	31.68	50.71	34.41	"
25.23	21.27	--	--	52.60	35.22	"
27.89	24.07	--	--	--	--	"
31.60	26.87	--	--	--	--	"
--	--	--	--	52.80	35.68	KF.HF+KF.2HF
30.72	27.54	41.70	33.05	50.74	36.57	KF.2HF
29.86	29.20	42.80	32.25	48.87	38.60	"
29.81	32.33	41.68	33.14	49.15	39.40	"
29.40	34.83	40.55	34.00	48.92	40.53	"
27.95	37.14	39.77	36.54	--	--	"
--	--	40.37	38.82	--	--	"
27.29	38.52	37.62	40.18	--	--	"

KF (Cont)

Equilibrium in the KF-HF-H_2O System

At 0°C		At 20°C		At 40°C		Solid Phase
Gms. per 100 gms. sat. sol.		Gms. per 100 gms. sat. sol.		Gms. per 100 gms. sat. sol.		
KF	HF	KF	HF	KF	HF	
26.77	40.35	35.37	41.90	46.24	42.98	2KF.5HF
26.66	42.10	34.42	44.20	44.70	44.46	"
26.42	44.30	--	--	43.40	46.21	"
26.82	45.83	--	--	42.75	48.03	"
25.59	45.09	34.00	45.27	--	--	"
24.02	45.42	31.00	47.55	38.17	50.54	KF.3HF
22.85	46.75	30.56	47.77	37.41	51.38	"
22.38	47.50	29.64	48.68	37.05	52.04	"
22.30	48.16	28.86	49.50	36.98	52.50	"
20.98	50.74	28.75	50.01	--	--	"
20.56	50.82	28.64	50.26	--	--	"
19.46	51.30	26.04	51.81	34.21	54.20	KF.4HF
18.00	52.08	21.36	55.30	31.46	55.76	"
15.87	54.01	18.67	58.58	29.68	56.74	"
12.50	57.60	17.64	62.23	27.74	58.07	"
10.68	60.57	17.45	64.12	26.25	60.54	"
9.86	64.13	18.36	66.60	--	--	"
10.30	68.10	19.20	67.15	--	--	"
12.01	69.80	--	--	--	--	"
14.17	71.57	--	--	--	--	"
15.85	72.42	--	--	--	--	"
19.84	73.27	--	--	--	--	"
23.62	74.60	--	--	--	--	"

KF (Cont)

Equilibrium in the KF-HF System

t°C	Mol Fraction HF in Solution	Solid Phase
-83.7	1.000	HF
-85.2	0.9875	"
-86.9	0.9732	"
-89.5	0.9580	"
-92.8	0.9466	"
-97.0	0.9311	" + KF.4HF
-45.0	0.9143	KF.4HF
8.0	0.8884	"
48.0	0.8572	"
63.2	0.8355	"
67.7	0.8241	"
71.8	0.8086	"
(72.0)	(6.8000)	"
72.0	0.7993	"
71.0	0.7901	"
67.8	0.7783	"
(63.6)	(0.771)	" + KF.3HF
64.4	0.7676	KF.3HF
65.4	0.7583	"
(65.8)	(0.7500)	"
65.8	0.7490	"
65.5	0.7438	"
64.5	0.7342	"
62.6	0.7278	"
62.4	(0.727)	" +2KF.5HF
62.7	0.725	KF.5HF
64.0	0.7173	KF.5HF
(64.3)	(0.714)	"
64.3	0.7115	"
63.4	0.7040	"
61.8	0.6969	" + KF.2HF
62.4	0.6932	KF.2HF
70.0	0.6777	"
71.7	0.6670	"
71.1	0.6606	"
68.3	(0.649)	"+ α KF.HF
84.	0.6435	αKF.HF
128	0.6197	"
148	0.6014	"
175	0.5695	"
189	0.5488	"
195	0.5382	" +βKF.HF
217	0.5218	βKF.HF
231	0.5103	"
234	0.5075	"
236.8	0.5032	"
(239.0)	(0.5000)	"
238.8	0.4996	"
236	0.4847	"
229.5	0.4860	" + KF
292	0.4775	KF
346	0.4646	"

KF (Cont)

Heat of Formation (Solid) - -135.6 Kcal/g mole
Heat of Formation (liquid)- -130.9 "
Heat of Formation (gaseous)- -205.4 "

Entropy at 298°K (solid) - 15.98 eu.
Entropy at 298°K (liquid - 18.20 eu.
Entropy at 298°K (gaseous)- 77.40 eu.
Heat Capacity Data:

Cp (solid - 300°K - 11.48 cal/g mole-°K
800°K - 13.71
1200 °K -14.76
Cp (Liquid) - 300°K to 2000°K - 16.00 cal/g mole-°K
Cp (gaseous) - 300°K - 17.30 cal/g mole°K
800°K - 19.97 "
1200°K - 19.73 "
1800°K - 19.78 "

K_2SiF_6

MW - 220.27

MP - Decomposition starts at 427°C

Density - 2.665 g/cm^3

Dissociation Pressure Data

Temperature °C	Pressure mm Hg
698	34.5
760	116.8
800	275.8
833	485.4
857	636.8
878	810.7
879	817.8

Solubility of K_2SiF_6 in H_2O

t°C	gms. K_2SiF_6 per 100 cc. sat. sol.	t°C	gms. K_2SiF_6 per 100 cc. sat. sol.	t°C	gms. K_2SiF_6 per 100 cc. sat. sol.
0	0.077	25	0.177	60	0.377
14	0.09	35	0.246	70	0.420
16	0.132	40	0.220	78	0.462
17	0.1147	45	0.268	88	0.500
20	0.113	55	0.322	100	0.82

Heat of Formation (Solid) at 298°K - -52.8 Kcal/g mole

Heat of Dissociation at 700°C - 21.2 Kcal/g mole

MgF_2

MW - 62.31
MP - 1266 °C
BP - 2239 °C
Solubility Data:
@ 18°C, .0076 g/100 g H_2O
(insoluble in hot water)
Heat of Formation (Solid) at 298°K - -268.7 Kcal/g mole
Heat of Formation (liquid) at 298°K - -259.6 Kcal/g mole
Heat of Formation (gas) at 298°K - -173.2 Kcal/g mole
Entropy (solid) at 298°K - 13.8 eu
Entropy (liquid) at 298°K - 15.4 eu
Entropy (gas) at 298°K - 61.9 eu
Heat Capacity Data:
Cp (solid) - 100°K - 0.27 cal/g mole-°K
300°K - 14.06 "
500°K - 16.81 "
800°K - 18.41 "
1500°K - 20.42 "
Cp (liquid) -300°K to 4000°K - 22.57 cal/g mole -°K
Cp (gas) - 100°K - 8.24 cal/g mole -°K
300°K - 11.06 "
500°K - 12.53 "
800°K - 13.41 "
1500°K - 13.72 "

NH_4HF_2

MW 57.0

MP 124°C

Density 1.503 g/cm^3

$(NH_4)_2SiF_6$

MW 178.14

Density 2.011 (oct.)

2.152 (hex.)

Solubility in H_2O 18.6 g/100 cm^3 H_2O @ 17°C

55.5 g/100 cm^3 H_2O @ 100 °C

Heat of Formation at 298°K -36.6 Kcal/g mole

NH_4F

MW 37.04

MP Sublimes

Density 1.315 g/cm^3

NH_4F solubility in H_2O @ 0°C 100 gms/100 ml H_2O

Soluble in alcohol

insoluble in NH_3

Heat of Formation -111.6 Kcal/g.mole

at 298°K

Heat Capacity Data

Temperature °C	Sp Heat cal/g mole °K
-69.9	12.62
-45.8	14.12
-35.4	15.34
-30.7	19.44
-25.0	14.26
1.4	16.18
10.7	15.06

Na_3AlF_6

MW 209.94

MP 1000°C

Density 2.90 g/cm^3

Heat of Formation at 298°K -789.90 Kcal/g mole

Entropy at 298°K 57.42 eu.

Heat Capacity Data (Solid)

100°K	9.52	Cal/g mole °K
300°K	46.92	"
500°K	58.87	"
800°K	72.74	"
1000°K	75.87	"

NaF

MW 41.99

MP 988°C

BP 1695°C

Density 2.558 g/cm^3

Vapor Pressure Data

Temperature C	Pressure mm Hg.
1077	1
1240	10
1363	40
1455	100
1617	400
1704	760

Solubility of NaF in H_2O

t°C	d* of sat. sol.	Gms. NaF per 100 gms. sat. sol.	t°C	Gms. NaF per 100 gms. sat. sol.
0		3.53	40	4.21
20		3.90	50	4.35
25	1.0384	3.98	60	4.47
30		4.05	80	4.66
35	1.0354	4.13	100	4.83

Solubility of NaF in aqueous HF at 20°C

Gms. per 100 gms. H_2O			Gms. per 100 gms. H_2O		
NaF.	HF.	Solid Phase.	NaF	HF.	Solid Phase.
3.96	0.0	NaF	2.46	1.16	NaF. HF
4.14	0.081	"	2.49	1.20	"
4.19	0.104	"	2.20	1.55	"
4.23	0.135	"	2.04	2.22	"
4.51	0.420	"	2.01	2.70	"
4.56	0.484	" +NaF.HF	1.88	4.17	"
3.45	0.660	NaF.HF	1.83	8.68	"
2.99	0.831	"	1.79	10.28	"

* d = density

NaF (Cont.)

Entropy at 298°K (solid) 12.31 eu

Entropy at 298°K (liquid) 17.83 eu

Entropy at 298°K (gas) 52.12 eu

Heat Capacity Data:

Cp (solid)	100°K	2.03	cal/g mole °K
	300°K	10.54	"
	500°K	12.25	"
	800°K	13.57	"
	1500 °K	16.64	"
Cp (liquid)	400°K	12.22	"
	700°K	13.32	"
	1100°K	16.68	"
Cp (Gas)	300°K	7.95	"
	1000°K	9.00	"
	2700°K	9.34	"

Critical Temperature 3075°C

Critical Pressure 1330 atms

Heat of Formation (Solid) at 298°K -137.11 Kcal/g mole

Heat of Formation (liquid) at 298°K -129.90 "

Heat of Formation(gas) at 290°K -70.09 "

Na_2SiF_6

MW 188.04

MP decomposition starts at 327°C

Density 2.679 g/cm^3

Vapor Pressure Data:

Temperature °C	Pressure mm Hg
516	19
572	63
629	163
682	387
709	620

Heat of Formation at 298°K -677 Kcal/g mole

Heat of decompositon for the reaction

$Na_2SiF_6(s) \rightarrow 2NaF\ (s) + SiF_4(g)$ is -28 Kcal/g mole

Solubility of Na_2SiF_6 in H_2O

t°C	Gms. Na_2SiF_6 per 100 gms. sat. sol. Average
0	0.41
10	.53
15	.60
16	.61
17.5	.63
20	.67
25	.75
30	.84
35	.94

t°C	Gms. Na_2SiF_6 per 100 gms. sat. sol. Average
40	1.02
45	1.12
50	1.22
55	1.33
60	1.44
70	1.68
78	1.92
80	2.17
90	2.42
100	

Na_2SiF_6 (Cont)

Solubility of Na_2SiF_6 in HCl Solutions

Gms. HCl per 100 gms. sat. sol.	Gms. Na_2SiF_6 per 100 gms. sat. sol.				
	0°C	15°C	20°C	25°C	40°C
0	0.39	0.58	0.64	0.72	0.99
	-	-	-	-	-
2.1	0.80	1.11	1.23	1.30	1.69
	(1.0178)*	(1.0191)	(1.0201)	(1.0211)	-
4.1	0.99	1.28	1.35	1.41	1.80
	(1.0292)	(1.0303)	(1.0310)	(1.0321)	-
6.0	0.96	1.23	1.30	1.37	1.71
	-	-	(1.0410)	(1.0408)	-
8.1	0.82	1.09	1.17	1.25	1.55
	(1.0505)	(1.0501)	(1.0495)	(1.0491)	-
10.1	0.68	0.92	1.02	1.12	1.37
	(1.0601)	(1.0596)	(1.0592)	(1.0589)	-
12.1	0.53	0.74	0.85	0.94	1.17
	(1.0699)	(1.0684)	(1.0678)	(1.0671)	-
14.0	0.39	0.55	0.66	0.76	0.97
	(1.0790)	(1.0771)	(1.0760)	(1.0749)	-
16.1	0.31	0.42	0.52	0.60	0.73
	(1.0893)	(1.0854)	(1.0850)	(1.0848)	-
19.6	0.30	0.40	0.45	0.52	0.61
	-	(1.1034)	(1.1026)	(1.1020)	-

*Numbers in parenthesis are liquid densities.

Na$_2$SiF$_6$ (Cont)

Solubility of Na$_2$SiF$_5$ in HF Solutions

	0°C		10°C		20°C		50°C
HF Wt.%	Gms. Na$_2$SiF$_6$ per 100 gms. Sat. Sol.	HF Wt%	Gms. Na$_2$SiF$_6$ per 100 gms. Sat. Sol.	HF Wt%	Gms. Na$_2$SiF$_6$ per 100 gms Sat. Sol.	HF Wt%	GMs. Na$_2$SiF$_6$ per 100 gms Sat. Sol.
0.1	0.46	0.	0.53	0	0.66	0	1.27
5.27	.63	5.65	.69	5.0	.84	-	-
15.53	.88	15.7	.89	15.0	.99	16.0	1.35
21.2	.90	21.2	.96	19.56	1.06	20.6	1.40
26.53	1.03	25.6	1.03	21.0	1.15	26.48	1.42

SiF_4

MW 104.09

MP -90.2°C

BP -65°C

Sp. Vol. 3.7 ft^3/lb @ 70°F; 1 atm.

Density of gas 4.67 g/liter @ 0°C, 1 atm.

Density of liquid 1.66 g/cm^3 @ -95°C, 1

Vapor Pressure Data;

Below 1 atm.

Temperature °C	Pressure mm. Hg
-144	1
-134.8	5
-130.4	10
-125.9	20
-120.8	40
-117.5	60
-113.3	100
-110.2	200
-100.7	400
-94.8	760

Above 1 atm.

Temperature °C	Pressure atms.
-84.4	2
-67.9	5
-52.6	10
-33.3	20

Solubility of SiF_4 in Organic Solvents at 30°C and 1 atm Total Pressure

Solvent	cc solvent	gms. sat. sol.
Methyl Alcohol (abs.)	--	32.8
Ethyl " (96.1 Wt.%)	--	39.0
" " (abs.)	57.2	36.4
" " (96.1 Wt.%)	60.8	37.8
" " (94.3 Wt.%)	61.5	38.1
" " (92.6 Wt.%)	63.4	38.8
" " (91.0 Wt.%)	63.9	39.0
Iso propyl alcohol (98%)	39.4	28.2

SiF_4 (Cont)

Amyl Alcohol	20.9	17.3
Glycol	--	26.2
Di ethylene glycol	--	26.2
Glycerol	--	5.7
Acetone (annydrous)	3.2	
Acetic Acid (glacial)	1.1	1.1
Pyruvic Acid (38-45%)	--	4.4

Critical Temperature 14.1°C

Critical Pressure 36.7 atm.

Heat of Formation @ 298°K -385.9 Kcal/ g mole

Heat of Sublimation @ -94.8°C_58.9 cal/gram

Entropy at 298°K 68 eu

Heat Capacity Data (gas):

100 °K	8.24 cal/g mole -°K
300 °K	16.13 "
500 °K	20.53 "
800 °K	23.56 "
1200 °K	24.79 "

UF_6

MW - 352.02

MP - 69.2 °C @ 2 atm.

BP - Sublimes @ 56°C @ 1 atm.

Density @ 21°C - 4.68 g/cm^3

Vapor Pressure Data:

Temperature °C	Pressure mm Hg.
-38.8	1
-13.8	10
4.4	40
18.2	100
42.7	400
55.7	760

Soluble in CCl_4

Decomposes in H_2O, ether, alcohol

Heat of Formation (gas) at 298°K -505 Kcal/g mole

Entropy (gas) at 298°K 90.76 eu.

Supplementary Solubility Data

CaF_2

Solubility of CaF_2 in Various Aqueous Solutions at 18°C

Aq. solution of:	Normality of aq. solvent	Gms. CaF_2 dissolved per liter
Acetic acid	0.083n* CH_3COOH	0.0308
" "	0.166n "	0.0383
" "	0.333n "	0.0407
" "	0.833n "	0.0498
Ammonia	1.0n NH_4OH	0.0176
"	1.66n "	0.0175
Ammonium Chloride	0.25n NH_4CL	0.0208
" "	0.50n "	0.0258
" "	1.0n "	0.0278
" "	1.66n "	0.0278
" Acetate	0.33n CH_3COONH_4	0.0203
" "	0.71n "	0.0219
" "	1.42n "	0.0245
" "	1.66n "	0.0255

* _n_ = normality

H_2SiF_6

MW 144.07

Equilibrium in the MgO - P_2O_5 - H_2SiF_6-H_2O System at 25°C

Solubility of $MgSiF_6$ in H_3PO_4 solutions: Solid Phase $MgSiF_6 \cdot 6H_2O$ throughout.

Gms per 100 gms. sat. sol.		
MgO	F	P_2O_5
5.7	16.5	0.0
4.6	12.5	7.7
4.3	10.3	13.0
2.9	7.0	21.8
2.2	4.8	27.9
1.5	2.8	33.5
1.5	3.0	35.3
0.7	1.7	45.1
0.6	0.8	55.5
0.5	0.7	57.7

Composition of Invariant Solutions:

Gms. per 100 gms. sat. sol.			
MgO	F	P_2O_5	Solid Phase
8.7	2.3	32.9	$MgSiF_6 \cdot 6H_2O + MgHPO_4 + Mg(H_2PO_4)_2 \cdot 2H_2O$
4.0	0.3	54.9	" $+ Mg(H_2PO_4)_2 + Mg(H_2PO_4)_2 \cdot 2H_2O$
8.3	0.0	33.1	$MgHPO_4 \cdot 3H_2O + Mg(H_2PO_4)_2 \cdot 4H_2O$
4.6	0.0	53.3	$Mg(H_2PO_4)_2 \cdot 2H_2O + Mg(H_2PO_4)_2 \cdot 4H_2O$
3.2	0.0	59.6	" $+ Mg(H_2PO_4)_2$

Equilibrium in the $PbSiF_6$ - H_2SiF_6 - H_2O System at 20°C

Gms. per 100 gms. sat. sol.		
H_2SiF_6	$PbSiF_6$	Solid Phase
0.0	68.97	$PbSiF_6 \cdot 4H_2O$
0.98	67.96	"
7.34	56.50	"
13.93	43.10	$PbSiF_6 \cdot 4H_2O$
25.82	23.95	"
39.65	10.38	"

KF

Solubility of KF in Anhydrous Organic Solvents

Solvent	t°C	Solubility
Methanol	18	10.0 gms. per 100 gms. CH_3OH (d.= 0.864)
	25	10.2 " (d.= 0.865)
Methanol	20	0.192 gms. per 100 gms. sat. sol.
	30	0.168 "
	40	0.150 "
	50	0.125 "
Ethanol	20	0.106 "
	30	0.096 "
	40	0.068 "
	50	0.023 "
	55	0.016 "
Propanol (99.6%)	23	0.34 gm. per 100 gms. sat. sol.
Acetone	18	0.00022 gms. per 1000 gms. actone
	37	0.00025 "
Acetonitrile	18	0.0036 gms. per 100 gms. acetonitrile
	25	0.0024 "

Equilibrium in the KF-NH_4F-H_2O System At 25°C

Gms. per 100 gms. sat. sol.		Solid	Gms. per 100 gms. sat. sol.		Solid
NH_4F.	KF	Phase	NH_4F	KF	Phase
0	48.96	KF.$2H_2O$	13.77	41.26	NH_4F
1.70	48.76	"	16.88	35.43	"
3.49	38.63	"	20.37	29.92	"

KF (cont)

6.53	48.15	"	26.44	23.76	"
8.04	48.42	"	31.59	16.85	"
10.08	47.88	"	36.03	10.69	"
10.77	47.93	NH_4F	41.27	4.57	"
11.09	47.39	"	42.92	1.48	"
12.14	45.09	"	44.85	0.00	"

Equilibrium in the $KF-NiF_2-H_2O$ System

Gms. per 100 gms. sat. sol.			Gms. per 100 gms. sat. sol.		
NiF_2	KF	Solid Phase	NiF_2	KF	Solid Phase
1.98	1.21	MC*	2.01	1.18	MC
1.20	3.52	"	1.12	4.30	"
0.80	6.32	"	0.26	9.25	"
0.52	9.64	"	0.03	15.4	"
0.40	12.9	"	0.01	19.2	"
0.01	16.8	"	--	22.1	"
--	20.2	"	--	25.0	"
--	25.5	"	--	27.7	"
--	28.1	"	--	31.3	"
--	33.0	"	--	36.8	"
--	37.5	"	--	41.3	"

Equilibrium in the $KF-C_2H_5OH-H_2O$ System at 25°C

Gms. per 100 Gms. Upper Layer			Gms. per 100 Gms. Lower Layer		
KF	C_2H_5OH	H_2O	KF	C_2H_5OH	H_2O
1.23	92.67	6.07	45.33	0.67	54.00
--	--	--	37.82	1.70	60.49
1.16	83.30	15.54	--	--	--
--	--	--	28.68	4.7	66.85

* MC = Mixed Crystals

KF (Cont)

2.86	65.81	31.33	--	--	--
4.47	57.4	38.13	20.90	11.9	67.2
5.47	53.04	41.49	--	--	--
--	--	--	18.55	15.6	65.85
6.93	47.52	45.55	--	--	--
8.84	41.28	49.88	15.7	21.8	62.5
9.55	38.66	51.79	--	--	--
--	--	--	13.57	27.27	59.15
10.52	35.91	53.57	--	--	--
--	--	--	11.43	33.23	54.34
11	30	59	11	30	59

Equilibrium in the KF-C_3H_7OH - H_2O System at 25° C

(Propyl Alcohol)

Gms. per 100 Gms. Homogeneous Liquid			Gms. per 100 Gms. Homogeneous Liquid		
KF	C_3H_7OH	H_2O	KF	C_3H_7OH	H_2O
0.17	96.78	3.05	8.15	7.49	84.36
0.31	78.91	21.19	10.00	5.97	84.03
0.62	66.29	33.09	12.21	4.39	83.41
0.81	59.97	39.22	14.18	3.45	82.37
1.29	47.46	51.21	18.75	1.89	79.35
1.77	35.40	62.83	25.83	0.74	73.43
2.50	19.05	78.45	35.38	0.23	64.38
5.32	10.64	84.04	47.62	0.039	52.34

Equilibrium in the KF-C_3H_5OH- H_2O System at 20°C

Results in terms of gms. per 100 gms. of solvent, alcohol + water

(isopropyl alcnol)

gms. per 100 gms. Solvent			Gms. per 100 gms. Solvent		
KF	$CH_3CHOHCH_3$	H_2O	KF	$CH_3CHOHCH_3$	H_2O
51.826	1.555	98.445	12.385	21.438	78.562
38.748	2.965	97.035	5.071	59.339	40.661

26.039	6.525	93.475	3.973	65.455	34.545
17.812	12.215	87.785	1.705	82.750	17.250

Equilibrium in the KF - Acetone - H_2O System at 20°C

Gms. per 100 gms. Homogeneous Mixture			Gms. per 100 gms. Homogeneous Mixture		
KF	$(CH_3)_2CO$	H_2O	KF	$(CH_3)_2CO$	H_2O
46.3	trace	53.7	9.17	23.53	67.30
44.24	0.24	55.52	5.00	38.72	56.28
33.34	1.00	65.66	3.06	47.89	46.84
29.86	1.60	68.54	1.38	58.06	40.55
25.74	3.02	71.24	0.979	62.60	36.42
20.28	5.90	73.80	0.75	65.41	33.84
16.31	9.72	73.97	0.50	69.58	29.92
12.40	15.59	72.01	0	98	2*

Equilibrium in the KF-KI-H_2O

Sat. Sol. Mole %		Sat. sol. mole %		Sat. sol. mole %	
KI	KF	KI	KF	KI	KF
13.92	0.0	9.42	4.74	3.78	12.25
12.58	1.34	7.49	7.10	2.22	15.30
10.08	4.34	6.22	8.81	1.21	18.97
9.44	4.69	5.19	10.53	0.0	23.92

K_2SiF_6

Equilibrium in the K_2SiF_6 – KBr-H_2O System at 25°C

Sat. Sol. Wt. %		
K_2SiF_6	KBr	Solid Phase
0.15	0.0	K_2SiF_6
.02	6.58	"
.02	7.92	"
.01	11.05	"
.09	17.14	"
.07	22.56	"
0.19	26.30	K_2SiF_6
.09	28.61	"
.05	33.26	"
.07	36.42	"
.09	40.05	"
.14	40.47	K_2SiF_6 + KBr
0.0	40.51	KBr

Solubility of K_2SiF_6 in Saturated KNO_3 and KCl at 17°C

Solvent	Gms. K_2SiF_6 per 100 cc. sat. sol.
Water	0.1147
Aq. Sat. KNO_3 Solution	0.0048
Aq. Sat. KCl Solution	0.0048

Solubility of K_2SiF_6 in Aqueous Ethanol Solutions at 14°C

Wt. Percent C_2H_5OH in Solvent	Gms. K_2SiF_6 per liter sat. sol.
0.0	0.9
8.7	0.46
15.9	0.21
27.3	0.09
42.4	0.05
50	0.039
93.7	0.0096

NH_4F

Equilibrium in the $CoF_2 - NH_4F - H_2O$ System

at 20°C

Gms. per 100 gms. sat. sol.		Solid
CoF_2	NH_4F	Phase
0.34	2.9	$CoF_2 \cdot 4H_2O$
0.21	9.7	"
0.08	12.4	$CoF_2.2NH_4F.2H_2O$
0.02	18.4	"
0.015	20.8	"
0.010	24.1	"
0.009	34.3	"

At 50°C

Gms. per 100 gms. sat. sol.		Solid
CoF_2	NH_4F	Phase
0.40	3.6	$CoF_2 \cdot 4H_2O$
0.08	14.5	$CoF_2.2NH_4F.2H_2O$
0.06	17.3	"
0.03	22.6	"
0.015	24.8	"
0.014	27.6	"
0.013	29.5	"

Equilibrium in the $CuF_2 - NH_4F - H_2O$ System at 20°C

Gms. per 100 gms. sat. sol.		Solid
CuF_2	NH_4F	Phase
2.15	2.2	$CuF_2 \cdot 2H_2O$
0.44	19.2	"
0.36	22.1	$CuF_2.2NH_4F.2H_2O$
0.55	27.8	
0.69	35.5	$CuF_2.2NH_4F.2H_2O$
0.53	41.9	" + NH_4F
0.52	44.1	NH_4F

Equilibrium in the $NiF_2 - NH_4F - H_2O$ System

at 20°C

Gms. per 100 gms. sat. sol.		Solid
NiF_2	NH_4F	Phase
1.07	3.4	$NiF_2.4H_2O$
0.91	6.4	"
0.72	9.4	"
0.51	10.4	$NiF_2.2NH_4F.2H_2O$
0.17	17.1	"
0.07	23.0	"
0.02	28.5	"
0.01	37.4	"
0.00	41.2	"

at 50°C

Gms per 100 gms sat. sol.		Solid
NiF_2	NH_4F	Phase
1.60	5.0	$NiF_2.4H_2O$
1.04	8.1	"
0.36	13.1	$NiF_2.2NH_4F.2H_2O$
0.15	17.7	"
0.10	20.5	"
0.04	26.2	"
0.02	32.4	"
0.01	37.3	"
0.0	41.5	"

NH_4F (Cont)

Equilibrium in the BeF_2 - NH_4F - H_2O System at 0°C

Gms. per 100 gms. sat. sol.		Solid	Gms. per 100 gms.sat. sol.		Solid
NH_4F	BeF_2	Phase	NH_4F	BeF_2	Phase
15.45	33.70	$BeF_2 \cdot NH_4F$	18.97	17.75	SS
15.60	30.40	"	17.50	18.21	"
16.50	28.50	"	16.20	10.60	" + $BeF_2 \cdot 2NH_4F$
18.76	26.90	"	17.40	8.76	$BeF_2 \cdot 2NH_4F$
19.90	25.10	"	19.08	7.00	"
21.80	24.70	"	20.60	6.30	"
21.74	25.00	"	25.85	5.06	"
21.80	25.10	" + SS	37.30	4.14	"
21.57	22.48	SS	43.40	2.49	"
20.37	22.05	"	43.20	0.50	NH_4F
20.15	20.16	"	43.40	0.0	"

SS = Solid Solution

Equilibrium in the CdF_2 - NH_4F- H_2O System at 20°C

Gms. per 100 gms. sat. sol.		Solid
CdF_2	NH_4F	Phase
4.0	1.6	CdF_2
2.4	5.4	"
1.8	12.3	"
0.4	20.8	$CdF_2 \cdot 2NH_4F \cdot 2H_2O$
0.87	28.9	"
0.57	40.9	"

Na_3AlF_6

Solubility of Na_3AlF_6 in Various Aqueous Salt Solutions at 25°C

Aluminum Nitrate		Aluminum Chloride		Aluminum Sulfate	
Moles per 1000 moles H_2O		Moles per 1000 moles H_2O		Moles per 1000 moles H_2O	
2 [Al $(NO_3)_3$]	$AlNa_3F_6$	Al_2Cl_8	$AlNa_3F_6$	$Al_2(SO_4)_3$	$AlNa_3F_6$
0.0	0.34	0.50	0.66	0.40	0.56
0.49	0.65	1.02	1.14	0.74	0.87
0.96	1.11	3.23	2.94	1.56	1.59
3.05	2.91	5.12	4.12	3.33	2.84
5.09	4.37	7.22	5.39	5.08	4.02
10.03	7.72	9.25	6.57	7.59	5.54
12.12	9.01	12.03	7.92	10.50	7.13
14.37	10.62	15.27	9.53	13.72	8.63
19.76	14.36	20.28	11.41	17.04	10.06

Ferric Nitrate		Ferric Chloride		Ferric Sulfate	
Moles per 1000 moles H_2O		Moles per 1000 moles H_2O		Moles per 1000 moles H_2O	
2[$Fe(NO_3)_3$]	$AlNa_3F_6$	2($FeCl_3$)	$AlNa_3F_6$	$Fe_2(SO_4)_3$	$AlNa_3F_6$
0.99	0.81	1.00	0.73	1.02	0.58
3.09	1.87	2.94	1.55	3.04	1.13
4.90	2.50	4.90	1.99	5.13	1.57
6.98	3.17	7.44	2.20	7.04	1.81
9.80	3.93	10.19	2.27	9.95	2.23
14.90	5.03	14.94	2.23	14.82	2.88
19.82	6.02	19.70	2.05	19.16	3.22
24.88	6.86	25.28	1.88	24.55	3.70

The solid phase in each case was unchanged cryolite.

NaF

Solubility of NaF in Aqueous Solution of H_2O_2 at 25°C

Wt. Percent H_2O_2 in Solvent	Gms Moles NaF per 1000 gms. solvent
0.0	0.9989
15.72	1.216
31.43	1.457

Equilibrium in the NaF - BeF_4-H_2O System

	Gms. per 100 gms. sat. sol.		Solid Phase		Gms per 100 gms. sat. sol.		Solid Phase
t°C	NaF	Na_2BeF_4		t°C	NaF	Na_2BeF_4	
0	3.81	0.22	NaF + Na_2BeF	60	3.85	0.47	NaF + Na_2BeF_4
20	3.84	0.26	" "	80	3.85	0.57	" "
40	3.76	0.45	" "	94	3.85	0.80	" "

Solubility of NaF in NaOH Solutions

Wt. Percent NaOH in Solvent	Gms. NaF per 100 gms. sat. solution at: °C				
	0°	20°	40°	80°	94°
0.0 (= H_2O)	3.99	4.10	4.47	4.48	4.73
0.81	3.49	3.40	3.51	3.56	3.47
1.67	--	2.89	--	--	--
2.30	2.65	2.70	2.81	2.82	3.03
2.70	2.37	2.45	2.70	2.84	2.73
5.66	--	1.68	--	--	--
7.90	--	1.25	--	--	--
18.40	--	0.38	--	--	--

Equilibrium in the NaF - Na_2SO_4-H_2O System

	Gms. per 100 gms sat. sol.		Solid		Gms. per 100 gms. sat. sol.		Solid
t°C	Na_2SO_4	NaF	Phase	t°C	Na_2SO_4	NaF	Phase
-3.0	0.0	3.92	Ice + NaF	25	8.67	2.35	NaF + 1.1
-1.12	4.07	0.0	" + Na.10	"	11.48	1.74	1.1
-3.06	1.68	3.42	" + " +NaF	"	21.34	0.37	" + Na.10
10.	0.0	3.92	NaF	"	31.71	0.0	Na.10
"	3.95	3.20	"	33.26	33.10	trace	" + Na.10+Na
"	6.39	2.98	" +Na.10	35	0.0	4.03	NaF
"	8.34	0.0	Na.10	"	4.34	3.18	"
15	0.0	3.93	NaF	"	8.62	2.50	" + 1.1
"	9.50	2.50	" + Na.10	"	9.58	2.09	1.1

NaF (Cont.)

"	11.70	0.0	Na.10	"	11.60	1.57	"
17.47	12.58	1.91	1.1+Na.10+NaF	"	18.11	0.62	"
25	0.0	3.98	NaF	"	32.80	trace	" +Na
"	4.48	3.13	"	"	32.96	0.0	Na

Na.10=$Na_2SO_4.10H_2O$; Na = Na_2SO_4; 1.1 = $NaF.Na_2SO_4$.

Solubility of NaF in Various Alcohols

t°C	Gms. NaF per 100 gms. sat. solution in: Methyl Alcohol Ch_3OH	Ethyl Alcohol C_2H_5OH	n Butyl Alcohol $CH_3(CH_2)_2Ch_2OH$
20	0.413	0.095	0.0030
30	0.440	0.108	0.0041
40	0.458	0.119	0.0043
50	0.476	0.158	0.0049
55	0.484	0.179	0.0054

Solubility of NaF in Acetone

t°C	d. of sat. sol.	Gms. NaF per 1000 per Acetone
18	0.792	0.000024
37	0.770	0.000027

Equilibrium in the NaF - NaCl-H_2O System

t°C	Gms. per 100 gms. sat. sol. NaCl	NaF	Solid Phase	t°C	Gms per 100 gms sal sol NaCl	NaF	Solid Phase
25	26.40	0.0	NaCl	35	26.18	0.34	NaCl+NaF
"	26.12	0.31	" +NaF	"	26.13	0.29	"
"	26.24	0.12	" "	"	18.43	0.54	NaF
"	0.0	3.98	NaF	"	5.41	2.38	"
35	26.62	0.0	NaCl	"	0.0	4.00	"

Na_2SiF_6

Equilibrium in the Na_2SiF_6 - H_3PO_4 - NaCl System

Results are expressed as gms. Na_2SiF_6 per 100 gms. sat. sol.

P_2O_5 Wt%	Wt% NaCl at 40°C			Wt.% NaCl at 80°C		
	0	2	4	0	2	4
1	1.10	-	-	2.07	-	-
5	1.15	-	-	2.01	-	-
10	1.09	0.196	0.105	1.9	0.73	0.38
15	0.95	.181	.100	1.75	.59	.34
20	.78	.127	.067	1.45	.47	.24
25	.61	.066	.043	1.25	.38	.18
With 0.6% Al_2O_3 added, the Solubility is increased:						
10	-	-	0.33	-	-	0.90
20	-	-	.25	-	-	.62
25	-	-	.19	-	-	.48

Equilibrium in the Na_2SiF_6 - NaCl - H_2O System at 15°C

Sat. Sol. Wt.%		
NaCl	Na_2SiF_6	Density
0.0	0.65	-
0.41	0.206	1.0047
1.18	0.079	1.0083
2.48	0.041	1.0171
4.12	0.028	1.0291
7.87	0.017	1.0562

Sat. Sol. Wt.%		
NaCl	Na_2SiF_6	Density
11.69	0.012	1.0835
15.00	0.009	1.1080
18.09	0.007	1.1337
26.29	0.006	1.2021
26.36	0.0	1.2023

Solubility of Na_2SiF_6 in aqueous solution of Na_2SO_4

Results at 17°C	
Gm. Moles Na_2SO_4 per 1000 gms. solvent	Gm. Moles Na_2SiF_6 per 1000 gms. sat. sol.
0.000	0.0329
0.050	0.0143
0.125	0.0068
0.250	0.0042
0.375	0.0034
0.500	0.0029

Results at 20°C	
Gm. Moles Na_2SO_4 per 1000 gms. solvent	Gm. Moles Na_2SiF_6 per 1000 gms. sat.sol.
0.000	0.0363
0.0050	0.0336
0.0100	0.0309
0.0150	0.0284
0.0250	0.0201
0.0500	0.0168

Equilibrium in the Na_2SiF_6 - HCl - NaCl System

Gms. per 100 gms. Sat. Sol.				
HCl	NaCl	Na_2SiF_6	Density	Solid Phase
0.0	2.06	0.07	1.0150	Na_2SiF_6
2.03	1.97	.19	1.0240	"
4.07	1.91	.21	1.0356	"
5.92	1.99	.20	1.0456	"
11.82	1.97	.12	1.0734	"
15.15	1.98	.11	1.0905	"
18.94	2.06	.07	1.1095	"
0.0	26.35	.013	1.2037	Na_2SiF_6 + NaCl
1.61	23.45	.034	1.1913	NaCl
3.20	21.09	.046	1.1794	"
4.80	18.80	.043	1.1685	"
7.66	14.67	.043	1.1522	"
12.01	9.35	.040	1.1312	"
13.46	7.85	.040	1.1265	"
17.67	4.03	.041	1.1194	"

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